Science Policy Study—Hearings Volume 12
SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

HEARINGS

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

OCTOBER 2, 3, 4, 22, 23, 24, 1985

[No. 163]

Printed for the use of the
Committee on Science and Technology

U.S. GOVERNMENT PRINTING OFFICE

57-279 O WASHINGTON : 1987

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, DC 20402

H701-29

COMMITTEE ON SCIENCE AND TECHNOLOGY

DON FUQUA, Florida, *Chairman*

ROBERT A. ROE, New Jersey
GEORGE E. BROWN, JR., California
JAMES H. SCHEUER, New York
MARILYN LLOYD, Tennessee
TIMOTHY E. WIRTH, Colorado
DOUG WALGREN, Pennsylvania
DAN GLICKMAN, Kansas
ROBERT A. YOUNG, Missouri
HAROLD L. VOLKMER, Missouri
BILL NELSON, Florida
STAN LUNDINE, New York
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
NORMAN Y. MINETA, California
MICHAEL A. ANDREWS, Texas
BUDDY MacKAY, Florida**
TIM VALENTINE, North Carolina
HARRY M. REID, Nevada
ROBERT G. TORRICELLI, New Jersey
RICK BOUCHER, Virginia
TERRY BRUCE, Illinois
RICHARD H. STALLINGS, Idaho
BART GORDON, Tennessee
JAMES A. TRAFICANT, JR., Ohio
MANUEL LUJAN, JR., New Mexico*
ROBERT S. WALKER, Pennsylvania
F. JAMES SENSENBRENNER, JR., Wisconsin
CLAUDINE SCHNEIDER, Rhode Island
SHERWOOD L. BOEHLERT, New York
TOM LEWIS, Florida
DON RITTER, Pennsylvania
SID W. MORRISON, Washington
RON PACKARD, California
JAN MEYERS, Kansas
ROBERT C. SMITH, New Hampshire
PAUL B. HENRY, Michigan
HARRIS W. FAWELL, Illinois
WILLIAM W. COBEY, JR., North Carolina
JOE BARTON, Texas
D. FRENCH SLAUGHTER, JR., Virginia
DAVID S. MONSON, Utah

HAROLD P. HANSON, *Executive Director*
ROBERT C. KETCHAM, *General Counsel*
REGINA A. DAVIS, *Chief Clerk*
JOYCE GROSS FREIWALD, *Republican Staff Director*

SCIENCE POLICY TASK FORCE

DON FUQUA, Florida, *Chairman*

GEORGE E. BROWN, JR., California
TIMOTHY E. WIRTH, Colorado
DOUG WALGREN, Pennsylvania
HAROLD L. VOLKMER, Missouri
STAN LUNDINE, New York
NORMAN Y. MINETA, California
HARRY M. REID, Nevada
RICK BOUCHER, Virginia
RICHARD H. STALLINGS, Idaho
MANUEL LUJAN, JR., New Mexico*
ROBERT S. WALKER, Pennsylvania
F. JAMES SENSENBRENNER, JR., Wisconsin
CLAUDINE SCHNEIDER, Rhode Island
SHERWOOD L. BOEHLERT, New York
TOM LEWIS, Florida
SID W. MORRISON, Washington
RON PACKARD, California

JOHN D. HOLMFELD, *Study Director*
HARLAN L. WATSON, *Science Consultant*
NANCY LINDAS, *Congressional Fellow*
R. THOMAS WEIMER, *Republican Staff Member*

---

*Ranking Republican Member.
**Serving on Committee on the Budget for 99th Congress.

CONTENTS

WITNESSES

PANEL 1: OVERVIEW OF SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

	Page
October 2, 1985:	
Dr. Albert H. Teich, head, Office of Public Sector Programs, American Association for the Advancement of Science, Washington, DC	2
Prepared statement	11
Dr. W. Henry Lambright, professor, The Maxwell School, Syracuse University; and director, Science and Technology Policy Center, Syracuse Research Center, Syracuse, NY	34
Prepared statement	41
Panel 1 discussion	62
Questions and answers for the record:	
Dr. Teich	71
Dr. Lambright	75

PANEL 2: SCIENCE IN THE DEPARTMENT OF DEFENSE

Colonel Donald I. Carter, USAF, Acting Deputy Under Secretary of Defense for Research and Advanced Technology, U.S. Department of Defense, Washington, DC; accompanied by Dr. Leo Young, Director, Research and Laboratory Management, U.S. Department of Defense, Washington, DC	77
Prepared statement	82
Dr. James A. Tegnelia, Acting Director, Defense Advanced Research Projects Agency, U.S. Department of Defense, Washington, DC	107
Prepared statement	110
Panel 2 discussion	117
Questions and answers for the record:	
Colonel Carter	126
Dr. Tegnelia	130
Dr. Richard D. DeLauer, former Under Secretary of Defense for Research and Engineering, U.S. Department of Defense, Washington, DC; and president, The Orion Group, Ltd., Arlington, VA	134
Prepared statement	137
Discussion	139
Questions and answers for the record	142
October 3, 1985:	
Dr. Michael M. Crow, assistant director for policy analysis, Ames Laboratory, Ames, IA	145
Prepared statement	155
Discussion	177
Questions and answers for the record	188

PANEL: SCIENCE IN THE U.S. DEPARTMENT OF AGRICULTURE

Dr. Terrence B. Kinney, Jr., Administrator, Agricultural Research Service, U.S. Department of Agriculture, Washington, DC	192
Prepared statement	196
Dr. John Patrick Jordan, Administrator, Cooperative State Research Service, U.S. Department of Agriculture, Washington, DC	208
Prepared statement	213

Page

October 3, 1985—Continued
Dr. Keith Huston, cochairman, National Agricultural Research Committee, and director-at-large, North Central State Agricultural Experiment Station Directors, Wooster, OH 225
Prepared statement 230
Maury E. Bredahl, W. Keith Bryant, and Vernon W. Ruttan, "Behavorial and Productivity Implications of Institutional and Project Funding of Research," *American Journal of Agricultural Economics*, October 1980, pp. 371-383 243
Panel discussion 256
Questions and answers for the record:
Dr. Kinney 264
Dr. Jordon 275
Dr. Huston 281

PANEL 1: MISSION AGENCIES AND EXTRAMURAL RESEARCH

October 4, 1985:
Dr. Alvin W. Trivelpiece, Director, Office of Energy Research, U.S. Department of Energy, Washington, DC 291
Prepared statement 294
Dr. Orville G. Bentley, Assistant Secretary, Science and Education, U.S. Department of Agriculture, Washington, DC 304
Prepared statement 310
Dr. Frank B. McDonald, Chief Scientist, National Aeronautics and Space Administration, Washington, DC 324
Prepared statement 327
Panel 1 discussion 345

PANEL 2: MISSION-AGENCY SUPPORTED EXTRAMURAL RESEARCHERS

Dr. William F. Miller, president and chief executive officer, SRI International, Menlo Park, CA 352
Prepared statement 357
Dr. Eugene H. Levy, professor and head, Department of Planetary Sciences; and director, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 367
Prepared statement 373
Dr. Marvin E. Ebel, associate dean, Graduate School, University of Wisconsin, Madison, WI; and George H. Dummer, director, Office of Sponsored Programs, Massachusetts Institute of Technology, Cambridge, MA, on behalf of the Council of Governmental Relations, Washington, DC 382
Prepared statement 390
Panel 2 discussion 410
October 22, 1985:
David Packard, chairman of the board, Hewlett-Packard Co., Palo Alto, CA 415
Prepared statement 417
Discussion 433
Questions and answers for the record 441

PANEL: SCIENCE IN FEDERAL LABORATORIES

Dr. Eugene E. Stark, Jr., chairman, Federal Laboratory Consortium; and industrial initiatives officer, Los Alamos National Laboratory, Los Alamos, NM 448
Prepared statement 453
Dr. Wilmont N. Hess, director, National Center for Atmospheric Research, Boulder, CO 475
Prepared statement 480
Panel discussion 493
Questions and answers for the record:
Dr. Stark 497
Dr. Hess 500
Dr. Franklin A. Long, Program on Science, Technology and Society, Cornell University, Ithaca, NY 504
Prepared statement 510

Page

October 22, 1985—Continued
Dr. Franklin A. Long, Program on Science, Technology and Society, Cornell University, Ithaca, NY—Continued
Discussion 525
Questions and answers for the record 528
October 23, 1985:
Dr. Gerold Yonas, acting deputy director and chief scientist, Strategic Defense Initiative Organization, Washington, DC 531
Prepared statement 542
National Security Decision Directive 189: National Policy in the Transfer of Scientific, Technical and Engineering Information, September 21, 1985 564
Discussion 566
Dr. Robert S. Cooper, president, Pollard Road Inc., Arlington, VA; and former Assistant Secretary of Defense for Research and Technology and Director, Defense Advanced Research Projects Agency, U.S. Department of Defense 569
Prepared statement 578
Discussion 592

PANEL: SCIENCE IN THE DEPARTMENT OF DEFENSE

Norman R. Augustine, senior vice president, Martin Marietta Corp., Bethesda, MD; and former Chairman, Defense Science Board, U.S. Department of Defense 600
Prepared statement 605
Rodney W. Nichols, executive vice president, The Rockefeller University, New York, NY; and chairman, American Association for the Advancement of Science [AAAS] Committee on Science, Arms Control and National Security 614
Prepared statement 620
Panel discussion 661
October 24, 1985:
Dr. Lew Allen, Jr., director, Jet Propulsion Laboratory, Pasadena, CA 668
Prepared statement 671
Discussion 680

PANEL: REGULATION-DRIVEN RESEARCH

Dr. Joseph M. Hendrie, Brookhaven National Laboratory, Upton, Long Island, NY; and former Commissioner, U.S. Nuclear Regulatory Commission 689
Prepared statement 693
Dr. Bernard D. Goldstein, professor and chairman, Department of Environmental and Community Medicine, UMDNJ-Rutgers Medical School, Busch Campus, Piscataway, NJ; and former Assistant Administrator for Research and Development, U.S. Environmental Protection Agency 699
Prepared statement 703
Thomas C. Jorling, professor of environmental studies, Williams College, Williamstown, MA; and former Assistant Administrator for Water and Hazardous Materials, U.S. Environmental Protection Agency 715
Prepared statement 720
Thomas C. Jorling, "Risk Assessment: Dissent From a Former User," *Governance*, Spring 1984, pp. 14–18 734
Panel discussion 728
Dr. Francis W. Wolek, director of research, College of Commerce and Finance, Villanova University, Villanova, PA; and former Deputy Assistant Secretary for Science and Technology, U.S. Department of Commerce 744
Prepared statement 748
Francis W. Wolek, "Guayule: A Case Study in Civilian Technology," *Technology in Society*, vol. 7, pp. 11–23, 1985 762
Francis W. Wolek, "The Business of Technology: A Board Guide to Profits and Progress," *Directors & Boards*, vol. 9, No. 4, 1985, pp. 29–46 775
Discussion 784

Page

Appendix 1—Additional statement for the record:
Dr. Joseph M. Pettit, president, Georgia Institute of Technology, Atlanta, GA, and member, DOD/University Forum, October 27, 1985 785
Appendix 2—Additional material submitted by Dr. Michael Crow:
"R&D Laboratories' Environmental Contexts: Are the Government Lab—Industrial Lab Sterotypes Still Valid?," Michael Crow and Barry Bozeman, 1985 788
Appendix 3—Additional materials for the record related to the U.S. Department of Agriculture:
"Summary: Needs Assessment for the Food and Agricultural Sciences—A Report to the Congress From the Secretary of Agriculture," Joint Council on Food and Agricultural Sciences, January 1984 876
"FY 1987 Priorities for Research, Extension, and Higher Education—A Report to the Congress From the Secretary of Agriculture," Joint Council on Food and Agricultural Sciences, June 1985 962
"The Mission of the Agricultural Research Service," Agricultural Research Service, U.S. Department of Agriculture, January 1983 1012
"Agricultural Research Service Program Plan," Agricultural Research Service, U.S. Department of Agriculture, miscellaneous publication No. 1429, January 1983 1061
"Agricultural Research Service Program Plan—6-Year Implementation Plan, 1984-1990," Agricultural Research Service, U.S. Department of Agriculture, February 1983 1135
Appendix 4—Additional materials for the record related to the U.S. Department of Defense:
"Report of the DOD Laboratory Management Task Force," Office of the Under Secretary of Defense for Research and Engineering, July 1980 1170
Dr. Robert J. Hermann, "USDRE Independent Review of DOD Laboratories," prepared for the Under Secretary of Defense for Research and Engineering, 22 March 1982 1234
"The Department of Defense Report on the Technology Base and Support of University Research," prepared for the Committee on Armed Services, U.S. Congress, March 1, 1985 1306
"The Department of Defense Report on the Selected University Laboratory Needs in Support of National Security," prepared for the Subcommittee on Research and Development of the Committee on Armed Services of the U.S. House of Representatives, April 29, 1985 1391
Appendix 5—Additional materials for the record related to the U.S. Department of Energy:
Memorandum for Assistant Secretaries, Director, Office of Energy Research, and Managers, Operations Offices, from Donald P. Hodel, Secretary of Energy, dated August 21, 1984. Subject: Guidelines on relationships between the Department of Energy and universities and colleges .. 1456
Memorandum for Assistant Secretaries, Director of Energy Research, and Managers, Operations Offices, from Donald P. Hodel, Secretary of Energy, dated July 5, 1985. Subject: Policy guidance for fiscal year 1985-90 multiprogram laboratory institutional planning 1460
"Guide to Energy R&D Programs for Universities and Other Research Groups," DOE/ER-0179, U.S. Department of Energy, Office of Energy Research, Washington, DC, June 1984 1473
"An Assessment of the Relationships Between the Department of Energy and Universities and Colleges, Volume I," DOE/S-0025, prepared by the University Programs Panel, a report of the Energy Research Advisory Board to the U.S. Department of Energy, Washington, DC, August 1983 1562
"The Department of Energy Multiprogram Laboratories," DOE/S-0015, prepared by the Multiprogram Laboratory Panel, a report of the Energy Research Advisory Board to the U.S. Department of Energy, Washington, DC, September 1982 1632
Appendix 6—Additional materials for the record related to the National Aeronautics and Space Administration:
Summary and perspective from "NASA 1986 Long-Range Program Plan," compiled by the Management Support Division, Office of External Relations, National Aeronautics and Space Administration, Washington, DC, August 1985 1693

Page

Appendix 7—Additional materials for the record related to Federal laboratories:
"Report of the White House Science Council Federal Laboratory Review Panel," Office of Science and Technology Policy, Executive Office of the President, Washington, DC, May 1983 1726
"Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel, Volume I—Summary Report," Office of Science and Technololgy Policy, Executive Office of the President, Washington, DC, July 1984 1762
"Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel, Volume II—Status Reports by Agencies," Office of Science and Technology Policy, Executive Office of the President, Washington, DC, July 1984 1794
Alvin M. Weinberg, "The Problem of Big Problems Revisited," contribution to the commemorative volume of Daimler-Benz, 1985 1857

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

WEDNESDAY, OCTOBER 2, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
TASK FORCE ON SCIENCE POLICY,
Washington, DC.

The task force met pursuant to call at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. FUQUA. Today is the first of 6 days of hearings on the topic "Science in the Mission Agencies and Federal Laboratories." These are the last of the scheduled hearings of the Science Policy Task Force for 1985.

Our Federal Government supports science not only through science agencies, such as the National Science Foundation, but also through mission agencies, such as the Departments of Defense, Agriculture and Energy, and the National Aeronautics and Space Administration. The mission agencies, the science agencies, and the regulatory agencies also perform research in their own laboratories. The purpose of these hearings is to examine their significant contribution to the U.S. research base.

These hearings will focus on five issues: first, coordination and management of Federal research programs; second, mission agency relationships with extramural research performers; third, the role of the mission agencies in the science and engineering infrastructure; fourth, regulation-driven research; and fifth, the role of the Federal laboratories.

During these 6 days of hearings, which will conclude October 24, we will hear from many distinguished witnesses. Some of them will represent mission or regulatory agencies, or the Federal laboratories. Others will speak as performers of research for the agencies or laboratories; and still others as advisors or independent experts.

In addition, we have also requested the Congressional Research Service to provide a comprehensive study of the role of the Department of Defense in providing support for scientific research. A draft will be provided to the witnesses for comments.

Today's hearing is divided into two parts. First, we have a panel overview of Science in the Mission Agencies and Federal Laboratories. Then we will hear a second panel of Defense Department research policymakers. And our final witness is a former Under Secretary of Defense for Research and Engineering who is now a private consultant.

PANEL 1: OVERVIEW OF SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

Mr. FUQUA. Let me now call panel No. 1. Our first witness is Dr. Albert H. Teich, head of the office of public sector programs of the American Association for the Advancement of Science. Our second witness is Dr. W. Henry Lambright, professor of political science and public administration at the Maxwell School of Syracuse University.

These two gentlemen have collaborated on a number of papers about the Federal laboratories and the Federal Government's organization for science and have written independently on these topics as well. Welcome gentlemen. We are very happy to hear from you. Dr. Teich, we will be pleased to hear from you at this time.

[A biographical sketch of Dr. Teich follows:]

DR. ALBERT H. TEICH

Albert H. Teich is Head of the Office of Public Sector Programs at the American Association for the Advancement of Science. This office is reponsible for AAAS activities in public policy and public understanding of science and technology. From 1980 through mid-1984, he served as manager of science policy studies at AAAS, heading the R&D Budget and Policy Project and serving as staff officer for the Committee on Science, Engineering and Public Policy. In 1980–1981, he directed a major AAAS project in support of the National Science Foundation's preparation of the second *Five-Year Outlook for Science and Technology*. Prior to joining AAAS, Dr. Teich was associate professor of public affairs and deputy director of the Graduate Program in Science, Technology and Public Policy at George Washington University. Between 1969 and 1976, he served in a number of research, administrative, and teaching positions at Syracuse University Research Corporation and the State University of New York, including director of research of SUNY's Institute for Public Policy Alternatives in Albany. He has been a consultant to many organizations and federal agencies, including the National Science Foundation, the National Academy of Sciences, and the House Committee on Science and Technology. Dr. Teich is the author of many articles and the editor of three books, *Scientists and Public Affairs* (MIT Press, 1974), *Technology and Man's Future*, 3rd ed. (St. Martin's Press, 1981), and *Science, Technology and the Issues of the Eighties: Policy Outlook* (Westview Press, 1982). He holds a B.S. in physics and a Ph.D. in political science, both from M.I.T.

STATEMENT OF DR. ALBERT H. TEICH, HEAD, OFFICE OF PUBLIC SECTOR PROGRAMS, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, WASHINGTON, DC

Dr. TEICH. Thank you, Mr. Chairman. It is a privilege for me to present this testimony to you at your hearings today. I have followed the work of the task force over the past several months, and I believe it can have a major impact on the source of science policy in this country. I am honored to have an opportunity to contribute to its work.

As head of the office of public sector programs at the AAAS, I devoted a great deal of my time and effort to the issue of science policy, particularly issues associated with Federal R&D. I should emphasize that, however, that I am presenting this testimony as an individual and views that I will express are my own, and should not be taken as representing positions of the AAAS.

Mr. Chairman, I have submitted my written statement for the record, and with your permission, I would like to summarize its main points.

Mr. FUQUA. We will make all of the statements today part of the record, and if you wish to summarize, please feel free to do so.

Dr. TEICH. Good. My purpose in this statement is to provide an overview of research in the mission agencies, a bit of historical context and some observations on trends and policy issues that need to be addressed and I hope this will set the stage for the task force's work over the next several days.

By mission agencies, I mean those Federal agencies which support research but whose primary purpose is not to support research itself, but rather pursuit of broader societal purposes. More than 30 agencies of the Federal Government support research. Most of these are mission agencies. In fact in general usage, only two of these agencies are considered nonmission or science agencies, NSF and NIH.

The distinction, however, is not a precise one. Well, of the two nonmission agencies, NSF is clearly a science agency. Its main purpose is support of bank research, as you know, across a broad spectrum of scientific and engineering fields. NIH is also classified as a science agency and certainly is one at least from the point of view of biomedical research communities, which sees its fundamental purpose of support basically on medical research from other points of view. NIH is also a mission agency whose mission is advancement of the Nation's health and improvement of medical practice, and that has served mainly through research.

On the other hand, although the Department of Energy is, of course, regarded as a mission agency, its program of general science and research is in many respects a science agency within the Department. It supports programs, the most basic kind of research, high energy physics, and operates in a manner that is quite different from the rest of the Department with little relation to DOE's energy mission.

Despite these ambiguities, the concepts of mission and nonmission agencies do make intuitive sense. And I think they are useful in understanding some important aspects of science policy.

Let me mention two empirical ways of distinguishing between mission and nonmission agencies that may be of help to you in these hearings. The first is the relative importance of research in the overall picture of the agency as reflected in its budget. That is the agency's research intensiveness. In my prepared statement, I have included a table which shows the total budget and the research expenditures and the ratios between the two. The table shows that 91 percent of the NSF budget and the 1984 budget of NIH budget went to research. That is table 1, which appears at the end of the statement. None of the mission agencies devote more than about 40 percent of their budgets to research, and most of them devote much less. For example, the Department of Transportation and Department of Education devote less than 1 percent of their overall budgets to research.

TABLE 1.—OVERALL BUDGET, RESEARCH AND R&D FUNDING LEVEL BY AGENCY, FISCAL YEAR 1984

[Budget authority, millions of dollars]

	Overall budget	R&D	Research	R&D as percent of overall budget	Research as percent of overall budget
Agriculture	$31,235	$871	$839	2.8	2.7
Commerce	2,016	358	294	17.8	14.6
Defense-military	258,150	27,337	3,055	10.6	1.2
Education	15,423	101	78	.7	.5
Energy	10,539	4,528	1,864	43.0	17.7
HHS	299,428	4,828	4,457	1.6	1.5
(NIH)	(4,494)	(4,253)	(3,906)	(94.6)	(86.9)
Interior	4,917	358	335	7.3	6.8
Transportation	28,594	465	69	1.6	.2
AID	1,316	192	139	14.6	10.6
EPA	4,064	260	173	6.4	4.3
NASA	7,316	2,822	1,709	38.6	23.3
NRC	466	191	191	41.0	41.0
NSF	1,328	1,203	1,203	90.6	90.6
VA	26,477	193	174	.7	.7

NOTE: Includes all agencies with more than $100 million in R&D. Figures for R&D and research are for conduct only; facilities are not included.

Source: Office of Management and Budget.

That is one way of looking at the difference between mission and nonmission agencies. The other way, the other empirical way of distinguishing between them, I owe to my friend, Henry Lambright, and has to do with style of research administration in the two types of agencies. Dr. Lambright, in a book called, "Governing Science and Technology," characterizes agencies as "science-oriented or society-oriented" and points out the difference between the two styles of research administration that one finds in those two agencies. For example, science-oriented agencies support research while society-oriented agencies purchase it. He notes that science-oriented agencies employ unsolicited proposals, peer reviewed by scientists and funded through grants, while society-oriented agencies tend to work through solicitations and review proposals internally and fund projects under contracts. He also notes that science-oriented agencies emphasize excellence as a criterion for funding and allow researchers to operate with considerable autonomy, whereas society-oriented agencies emphasize relevance and are more concerned about accountability and responsiveness to their own needs. There are a couple of other differences, some noted in my statement, and others described more fully in Professor Lambright's book.

But these, of course, are not pure types. Most agencies reflect a mix, often with differences between their subunits. In fact, these differences, as I have described them, are a little bit of characterizations, but they do capture the different ties well-known to anyone who has dealt with Federal R&D.

Let me turn now very briefly to a history of mission agency research. Probably the most important point is that the history of science in the Federal Government is mostly that of the mission agencies. The science agencies, NSF and NIH, are in fact, in the long view, relatively recent additions to the scene. A good source of in-

formation on that history, which I will not review in detail, is the National Science Board's report, "Basic Research in the Mission Agencies" published in 1978, which I know has been utilized by the task force in preparing for these hearings.

The rise of science in the mission agencies begins in the early days of the Republic with surveys and explorations funded by various Federal agencies. Systemic research closer to what we know now today began to grow in the Agriculture Department through the Hatch Act, which set up the land grant colleges of the Civil War era and later in the 19th century. Other mission agency research began early in this century with the Bureau of Standards and the work of Bureau of Mines, and subsequently the National Advisory Committee on Aeronautics—which, of course, was later transformed into the NASA, the space agency.

Interestingly, this Nation saw relatively little need to support military research except during war time, and even when the Naval Research Laboratory was set up after World War I, it was given relatively little money. Of course, the Second World War and experience with science and technology in that context changed all of this, and in its aftermath arose a new role for the Federal Government in support of basic research.

The centerpiece of this new Federal role was the National Science Foundation, which came about as a result of a recommendation in the Bush report, "Science: The Endless Frontier." But this centerpiece was actually quite a small component of Federal research support since the mission agencies grew quite rapidly during the post-war period. Rather than taking over support of research in the post-war environment, NSF began to be viewed as more of a "balance wheel," filling in where needed among the programs of other agencies.

On the current scene, the mission agencies continue to play dominant roles in many areas of research. In table 2, in my statement, I have calculated the percentage distribution by agencies of Federal funds for the major disciplines of research for fiscal year 1984, including both basic and applied research. The results are quite eye-opening to someone who hasn't thought or looked at these figures. The mission agencies really dominate most areas of research. The Defense Department, for example, provided nearly 23 percent of all Federal funding for physical science research, 50 percent of Federal funding for math and computer science research, and almost a third of Federal support for psychology. NASA and DOE also support large shares of physical science and environmental science and engineering research. NSF shares are smaller. In fact, in only one area, environmental sciences, does NSF support the largest single share of research, and here its portion is over one-fourth.

TABLE 2.—PERCENTAGE DISTRIBUTION OF RESEARCH BY AGENCY FOR MAJOR FIELDS OF SCIENCE, FISCAL YEAR 1984

[Based on estimated obligations]

	Total	Life sciences	Psych.	Phys. sciences	Envir. sciences	Math/ computers	Engin.	Social sciences	Other
Agriculture	5.6	10.2	[1]	2.3	1.1	2.9	1.5	21.8	.....
Commerce	1.9	.2	.1	1.7	12.5	3.1	1.0	1.6	3.4
Defense	19.8	4.2	32.6	22.5	16.5	50.2	41.2	.9	23.8
Education	.6	.3	1.1	.....	.....	.....	.2	11.9	.....
Energy	13.7	2.8	.....	43.7	7.0	5.4	12.3	1.2	11.6
HHS	29.8	67.7	53.8	3.1	.....	2.9	1.2	29.9	51.1
(NIH)	(25.8)	(61.2)	(19.3)	(3.1)	.....	(2.8)	(1.2)	(4.2)	(46.5)
Interior	2.7	1.9	.....	.4	11.8	1.3	3.3	.5	[1]
Transportation	.5	.1	.2	[1]	[1]	.7	1.7	2.0	.1
AID	1.1	2.7	.....	.....	.....	.3	.1	.8	1.6
EPA	1.2	1.2	.3	.5	3.0	1.0	1.0	2.4	.6
NASA	11.3	1.0	1.1	13.4	21.4	12.2	25.6	[1]	.5
NRC	1.3	.....	.....	.....	.....	.....	5.4	.....	.....
NSF	8.2	3.9	5.6	11.6	26.1	18.8	5.0	8.0	6.9
VA	2.0	3.3	4.2	.....	.....	.....	.1	.....	.....
Other	.3	.5	1.0	.8	.6	1.2	.4	19.0	0.7
Total:									
Percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Amount [2]	$15,108	$5,749	$264	$3,003	$1,279	$446	$3,552	$482	$334

[1] Less than 0.1 percent.
[2] In millions.

Source: National Science Foundation.

The numbers are somewhat different if one focuses only on basic research instead of basic and applied, which I have just done. Those figures are shown in a separate table, table 3, with the overall message the same. Mission agencies provide a larger share of Federal support for most science fields. The only major exception to that is in the life sciences where a single agency—NIH—supports by far the largest share of research in biological and medical sciences, 75 percent. In many ways this seems to be a special case.

TABLE 3.—PERCENTAGE DISTRIBUTION OF BASIC RESEARCH BY AGENCY FOR MAJOR FIELDS OF SCIENCE, FISCAL YEAR 1984

[Based on estimated obligations]

	Total	Life sciences	Psych.	Phys. sciences	Envir. sciences	Math/ computers	Engin.	Social sciences	Other
Agriculture	5.5	8.9	([1])	2.4	0.8	2.0	2.7	16.6	.....
Commerce	.3	([1])	([1])	.9	.....	.9	.2	([1])	.....
Defense	11.7	2.8	19.8	11.7	16.8	46.0	33.8	1.3	26.0
Education	.2	.....	.....	.....	.....	.....	.....	8.3	.....
Energy	12.1	1.0	.....	39.8	2.1	6.3	10.4	.....	1.3
HHS	40.0	78.4	62.8	3.9	.....	3.0	3.5	26.0	.....
(NIH)	(37.4)	(75.2)	(23.6)	(3.9)	.....	(2.9)	(3.5)	(3.7)	49.1
Interior	1.8	.2	....	.2	10.2	.7	5.9	.3	.....
Transportation	([1])	.....	.....	.....	.....	.....	([1])	.....	.....
AID	([1])	.1	.....	.....	.....	([1])	([1])	.3	.....
EPA	.3	.3	([1])	.1	.6	.2	.7	1.7	([1])
NASA	9.9	.6	1.8	20.5	16.9	4.6	24.2	.2	1.0
NSF	16.8	6.5	13.5	19.4	52.0	35.6	18.5	21.0	22.1
VA	.2	.4	1.3	.....	.....	.....	.....	.....	.....

TABLE 3.—PERCENTAGE DISTRIBUTION OF BASIC RESEARCH BY AGENCY FOR MAJOR FIELDS OF SCIENCE, FISCAL YEAR 1984—Continued

[Based on estimated obligations]

	Total	Life sciences	Psych.	Phys. sciences	Envir. sciences	Math/ computers	Engin.	Social sciences	Other
Other	1.2	1.1	.8	1.1	.6	.7	.1	24.3	0.5
Total:									
Percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Amount [2]	$6,981	$3,243	$109	$1,751	$636	$228	$785	$150	$79

[1] Less than 0.1 percent.
[2] In millions.

Source: National Science Foundation.

Where the science agencies are most important, and the role of the mission agencies is consequently least evident, is in overall support of basic research at universities and colleges contained in table 4 in my statement. As that table shows, nearly three-fourths, 73 percent, of federally funded basic research at colleges and universities is funded by the two science agencies, NIH and NSF. Nearly half in fact is supported by NIH alone.

TABLE 4.—FEDERAL FUNDING FOR BASIC RESEARCH AT UNIVERSITIES AND COLLEGES, FISCAL YEAR 1984

[Estimated obligations, millions of dollars]

	Amount	Percent
Agriculture	$120.9	3.5
Commerce	.9	([1])
Defense	395.5	11.3
Education	4.9	.1
Energy	172.4	4.9
HHS	1,765.5	50.4
(NIH)	(1,699.4)	(48.5)
Interior	12.9	.4
Transportation	.2	([1])
AID	1.7	([1])
EPA	10.5	.3
NASA	155.4	4.4
NRC	0	0
NSF	856.1	24.4
VA	0	0
Other	5.2	.1
Total	3,502.1	[2] 99.8

[1] Less than 0.1 percent.
[2] Figures do not add to 100 percent due to rounding.

Source: National Science Foundation.

Most of the mission agencies contribute relatively smaller shares to overall support of academic basic research—Agriculture, about 3½ percent, Energy, about 5, Defense 11, NASA, 4 percent, and all off the others less than 1 percent each. On the other hand, because mission agencies tend to concentrate their support in limited numbers of areas, their support is more important in universities and colleges in those specific fields. For example, the Agriculture Department, of course, is most active and most important in universi-

ties' agricultural research as you will hear later on during these hearings.

Well, my observations of current policy environments suggest a number of trends and issues bearing on research in the mission agencies that I believe merit the task force's attention. Let me mention briefly five of these.

The first has to do with funding levels. The Reagan administration's science policies have had mixed effects on research in the mission agencies. Despite a period of austerity on the civilian side of the budget, the administration, with the support of the Congress, has gained substantial increases for basic research during the past four years. The science agencies—NSF and NIH—have done particularly well, but DOE, NASA, DOD have also recorded real growth in their basic research programs during this period. Table 5 presents the figures in current dollars, not including the effects of inflation.

TABLE 5.—FEDERAL FUNDING FOR RESEARCH AND BASIC RESEARCH BY AGENCY, FISCAL YEAR 1981 AND FISCAL YEAR 1985

[Obligations in millions of dollars]

	Basic research			Research		
	Fiscal year 1981	Fiscal year 1985	Percent change	Fiscal year 1981	Fiscal year 1985	Percent change
Agriculture	$314	$420	33.8	$741	$870	17.4
Commerce	16	18	12.5	249	220	−11.6
Defense	604	913	51.2	2,601	3,319	27.6
Education	21	14	−33.5	54	77	42.6
Energy	586	944	61.1	1,414	2,213	56.5
HHS	1,900	2,926	54.0	3,492	4,605	31.9
(NIH)	(1,767)	(2,738)	(55.0)	(2,948)	(4,003)	(35.8)
Interior	81	103	27.2	370	351	−5.1
Transportation	1	0.4	−60.0	89	80	−10.1
AID	0	4	0	86	249	189.5
EPA	11	25	127.2	218	200	−8.3
NASA	531	826	55.5	1,407	1,914	36.0
NRC	0	0	0	220	168	−23.6
NSF	897	1,336	48.9	955	1,414	48.1
VA	15	15	0	128	175	36.7
Other	64	94	46.9	189	179	−5.3
Total	5,041	7,638	51.5	12,213	16,034	31.3

Source: National Science Foundation.

At the same time, the administration has sought to reduce fund for applied research, development and demonstration programs in the nondefense agencies on the grounds that such efforts are more appropriate for the private sector. The reductions in applied research programs have been substantial in a number of agencies, including DOE's civilian programs, the National Oceanic and Atmospheric Administration—NOAA—in the Department of Commerce, Interior, and EPA.

These countervailing trends present several concerns. One, first of all, is that the distinction between basic and applied research is not all that clearcut, and thus these changes may not necessarily produce the intended effects. For example, reductions in NOAA's applied research programs may have significant negative impacts

on what many regard as basic research in atmospheric sciences and oceanography.

Apart from this, the increase in basic research has been based largely on the belief that it will contribute to economic growth and national security. Without disputing this belief, one might argue that it is equally important for the Federal Government to support generic applied research efforts as a means of facilitating the utilization of basic knowledge in practical applications. Thus, current policies on basic and applied research may actually be working against one another.

Finally, the reductions in applied research programs may be having negative impacts on institutions—Federal laboratories, university research centers, et cetera—that are affecting their ability to conduct basic research.

The proposed establishment of a Department of Science, as you know, this issue, which is kind of perennial, has arisen again in the past few months, and I don't wish to get involved in a discussion of the pros and cons of that proposal. My prepared statement summarizes a few of them, but I do want to simply point out that the issues having to do with the departmental proposal are deeply involved with research in the mission agencies. And I would also want to voice my concerns that the impacts on the mission agencies, the potential impacts that might result from creation of such a department have to be weighed if this topic gets debated seriously. I don't think they have received much attention in the discussions of the department.

My third point has to do with priorities among fields. I would mention that because of the way in which research budgets are disbursed among the mission agencies. The key priority decisions in research are made in the context of several different agency budgets, with relatively little opportunities for cross-comparisons on the basis of criteria related to science. In other words, basic research in agriculture competes mainly with other agricultural priorities while high energy physics competes not so much with other areas of science, but with energy programs.

The only executive branch units really capable of taking an overview of the basic research system, the Office of Management and Budget and the Office of Science and Technology Policy, affect it mainly at the margins. The diffusion of responsibility for basic research in the Congress means that even if the administration should prepare a budget with carefully weighted choices among fields of science, it would not be likely to receive a coherent legislative review.

Nonetheless, it is worth asking whether the present allocations are optimal, either in terms of the needs of the scientific community or the potential applications to which the research might eventually be put. There may not be a scientific way to answer the question of whether biomedical research and high energy physics merit their current levels of support relative to, say, materials science or anthropology, but raising the questions may still be a useful contribution to the political process through which resources for research in both the mission and nonmission agencies are allocated.

My fourth point has to do with the responsibility of the mission agencies for the research infrastructure. Over the past several years, it has become apparent that the infrastructure of U.S. science requires more attention than it has been receiving. The state of science education at all levels, the obsolescence of scientific instrumentation in universities, the condition of academic laboratories and other facilities, the participation of minorities, women, and other under-represented groups have all been the subject of study and discussion. All need to be addressed through action.

The problem of facilities, in particular, has given rise to several instances in which universities have sought to obtain funds through direct intervention in the legislative process, bypassing traditional peer review procedures. In the past, mission agencies played a significant role in the supporting university research facilities, through such efforts as NASA's Sustaining University Program and DOD's Centers of Excellence Program. The continued importance of research in the mission agencies to U.S. science, as discussed earlier in this statement, dictates that solutions to infrastructure problems must involve the mission agencies in more than a token manner. The Committee on Science and Technology is aware of this and the recent legislation on university facilities—H.R. 2823, Universities Research Facilities Revitalization Act of 1985—introduced by the chairman deserves support and encouragement.

Research management in the mission agencies. The discussion of differences between science-oriented and society-oriented research administration which I presented earlier in this statement suggests some of the continuing tensions which face mission agency research at the operational level. In general, these tensions stem from the researchers' desire for autonomy in their work to pursue the most promising and rewarding avenues from a scientific standpoint, versus the agencies' need to direct the research into areas most relevant to their missions. When managed creatively, these tensions can help stimulate extremely productive work, as is the case in some of the Nation's best industrial laboratories. But, when the tensions are manifested in rigid bureaucracies and increasingly confining regulations, the results are antithetical to the conduct of good research.

This is not a new issue, but as I have tried to show, research in the mission agencies is not a new phenomenon. That research is a source of continuing strength for U.S. science and technology and the conditions that help it to flourish need continuing attention. That is why these hearings are so important.

Thank you, Mr. Chairman. That concludes my statement, and I will be happy to answer questions.

[The prepared statement of Dr. Teich follows:]

Statement of

Dr. Albert H. Teich

Head, Office of Public Sector Programs

American Association for the Advancement of Science

Washington, D.C.

before the

Task Force on Science Policy

Committee on Science and Technology

U. S. House of Representatives

Hearings on Science in the Mission Agencies and Federal Laboratories

2318 Rayburn House Office Building

Washington, D.C.

October 2, 1985

Mr. Chairman and Members of the Task Force:

It is a privilege for me to present this testimony to you at your hearings on research in the mission agencies and national laboratories. I have followed the work of the Task Force over the past several months and I believe it can have a major impact on the course of science policy in this nation. I am honored to have an opportunity to contribute to its work.

As head of the Office of Public Sector Programs of the American Association for the Advancement of Science (AAAS), I devote much of my tim and effort to issues of science policy, particularly policy and administrative issues associated with federal research and development programs. I should note, however, that I am presenting this testimony as an individual. The views I will express are my own and should not be taken as representing positions of the AAAS.

I. INTRODUCTION

A major portion of federally-funded research is supported by agencies whose primary purpose is not support of science but rather the pursuit of broader societal purposes. These "mission agencies," as they are termed in science policy discussions, include such diverse entities as the Department of Defense, the Environmental Protection Agency and the Department of Commerce. In general, research is supported by these agencies not for the sake of advancing knowledge (although this is certainly a known and desired outcome), but rather as a means of contributing to the achievement of the agency's goals. At the same

time, this research plays a key role in the support and advancement of U.S. science and engineering. My purpose in this statement is to provide an overview of research in these mission agencies, a bit of historical context, and some observations on trends and policy issues that need to be addressed. I hope this will help set the stage for the Task Force's consideration of this important topic over the next several days.

II. WHAT ARE THE MISSION AGENCIES AND WHAT DISTINGUISHES THEM FROM NON-MISSION AGENCIES?

More than thirty agencies of the federal government support research and development activities. In general usage, only two of these agencies are considered non-mission or science agencies -- the National Science Foundation (NSF) and the National Institutes of Health (NIH). All of the others (with the possible exception of the Smithsonian) are termed mission agencies.

In the case of NSF the distinction is significant and relatively straightforward. NSF's main purpose is the support of basic research (mainly but not exclusively in universities and colleges) across a broad spectrum of scientific and engineering disciplines. For the others, however, the line between mission and non-mission is not all that clear.

NIH, for example, is certainly a science agency from the point of view of the biomedical research community which sees its fundamental purpose as the support of basic biomedical research. The Institutes operate with considerable autonomy, support a great deal of university

research, and even conduct their in-house programs much in the style of academic institutions. From the point of view of many policymakers, medical care practitioners, and interest groups, however, NIH is a mission agency whose mission -- the advancement of the nation's health and the improvement of medical practice — is served mainly through research. Furthermore, NIH, despite its considerable operational autonomy, is not a freestanding agency but an administrative unit of the Public Health Service (PHS). The PHS, in turn, is a part of the Department of Health and Human Services (DHHS), a huge department with a broad and important mission in which research is only a small element.

Similarly, the program of General Science and Research in the Department of Energy (DOE) is in many respects a science agency within its department. It suports perhaps the most basic of all basic research, high energy physics, through a program often described as a "national trust," which operates in a manner quite different from the rest of the department and has little relation to DOE's energy mission.

These ambiguities aside, the concepts of mission and non-mission agencies do make intuitive sense and, as these hearings will no doubt show, are useful in understanding some important aspects of science policy.

Perhaps the most direct way of distinguishing between mission and non-mission agencies is in the relative importance of research to the agency, as reflected in its budget — i.e., the agency's research intensiveness. Table 1 displays the overall budgets, research and R&D

funding levels, and the ratios of research and R&D funding to overall budget for the major federal research agencies in fiscal year 1984. These measures are similar to R&D as a percent of sales, a metric commonly used in comparing industrial firms and sectors.

Here the differences between the science agencies — NSF and NIH, with ratios of research to total budget of 91 and 87 percent, respectively — and the mission agencies are clearly evident. It is easy to understand how research in NSF and NIH, where it is practically the agencies' exclusive function, is treated differently than that in the mission agencies. It is also apparent that mission agencies differ substantially among themselves in the share of their resources devoted to research. For example, the Department of Transportation spends only 0.2 percent of its budget on research, while NASA spends nearly a quarter of its total funding on research (and nearly 40 percent on R&D). These differences can be seen in comparing the administrative orientations of mission and non-mission agencies.

As Lambright noted a number of years ago, research administration in NSF and NIH can be characterized as "science-oriented," while that in the mission agencies is "society-oriented."(1) Among the differences between the two styles are the following:

- Science-oriented agencies <u>support</u> research; society-oriented agencies <u>purchase</u> it.

- Science-oriented agencies employ unsolicited proposals, peer reviewed by scientists and funded through grants; society-

oriented agencies prefer to work through solicitations, review proposals internally and fund projects under contracts.

- o Administrators in science-oriented agencies view extramural researchers as "colleagues"; society-oriented administrators see them as "performers."

- o Science-oriented agencies emphasize excellence as a criterion for funding and allow researchers to operate with considerable autonomy; society-oriented agencies emphasize relevance and are more concerned about accountability and responsiveness to their own needs.

These are not, of course, pure types. Most agencies reflect a mix, often with differences among subunits. Nonetheless, as indications of central tendencies in administration the differences are real. The predominant mode in NSF and NIH is certainly "science-oriented" in these terms, while that in other agencies is -- with occasional exceptions -- "society-oriented."

III. HISTORICAL PERSPECTIVE

Mission agency research has a long and distinguished history in the United States. In fact, several of the mission agencies were supporting research long before the science agencies came into existence. The history of science in the federal government prior to World War II is almost entirely that of the mission agencies. In this statement I will only mention a few of the highlights of that history. Excellent

historical reviews are contained in several books and the National Science Board's extensive and detailed report, Basic Research in the Mission Agencies, published in 1978. (2)

Prior to the Civil War most governmental uses of science and engineering research were relatively small scale and ad hoc in nature. The federal government sponsored a considerable amount of exploration and mapping, as well as, a number of Coast and Geodetic Surveys (functions now conducted by the National Ocean Survey in the Department of Commerce). The Army Corps of Engineers and U.S. Military Academy were established early in the 1800s; the Smithsonian was created (through the bequest of a foreigner) during that period; and there were several attempts (none successful) to create a national university.

Federal funding of agricultural research in land grant colleges and state agricultural experiment stations had its origins in the Morrill and Hatch Acts of the Civil War era and late nineteenth century, and the National Academy of Sciences was established during this period as well. Research on basic standards and related problems, growing out of the need to standardize weights and measures for commerce, began with the creation of the National Bureau of Standards early in the twentieth century. And in the same period, mining research programs developed in the Bureau of Mines. The National Advisory Committee on Aeronautics (NACA), the forerunner of NASA, was established in 1915 and was followed some years later by the establishment of the National Institute (now Institutes) of Health. Military research became

institutionalized after World War I, with the creation of the National Research Council (NRC) in association with the National Academy of Sciences. The NRC was intended to coordinate the work of scientists outside the government with that of government. A permanent Naval Research Laboratory was also established after the war although -- as was the case with other peacetime military research prior to World War II -- funding was at a rather low level.

Mission agency research, like virtually all other governmental activity, was much smaller in absolute terms in the pre-World War II era. One estimate is that the whole federal R&D budget in 1939 was only $50 million.(3) Although statistics are not readily available, it is probably fair to say that mission agency research in those days was also smaller relative to other government activties than it is now -- i.e., the agencies were less research intensive -- and performance of research was more heavily intramural.

World War II was a great watershed for U.S. science and technology. The dramatic demonstration of the power of organized research and development to yield practical results of unprecedented importance, including of course the atomic bomb, completely changed the scale, direction and course of science and technology in the federal government and the nation as a whole. Of primary importance was the acceptance, marked by the Bush Report, Science -- The Endless Frontier, of a major federal role in the support of basic research.

The proposed creation of a new federal science agency -- a National Research Foundation, later the National Science Foundation -- was

central to the new federal role. But the Foundation's position was never intended to be an exclusive one. The mission agencies were to retain their applied research activities, while the new agency was to support basic research across all fields in a manner unhindered by demands for near-term results.(4) Later, as the postwar structure evolved and basic research programs became institutionalized in many of the mission agencies, a different concept developed for NSF. The Foundation, whose funding level was quite small relative to other federal research agencies -- in FY 1960, NSF represented less than 1 percent of federal R&D funding -- began to be viewed as a "balance wheel," filling in where needed among the programs of the other agencies.

Research in the mission agencies grew rapidly in the postwar years with defense leading the way. The Defense Department, together with the weapons and other military-related research functions of the Atomic Energy Commission, dominated growth of federal R&D. In the late 1950s, in response to Sputnik, these agencies were joined by a rapidly growing National Aeronautics and Space Adminstration (NASA).

Health, environment and other nondefense areas began to receive increased emphasis in the late 1960s with the advent of the Great Society's social programs and the widespread political sentiment that the fruits of federal science and technology should be applied to pressing national needs. Expanding federal responsibilities in energy and environment, and new regulatory roles, combined with a slow-down in defense and space spending shifted the balance during the 1970s.

More recently, with a new spurt of growth in military spending and austerity in nondefense programs, the balance has begun to swing back in the other direction -- although funding for basic research (in particular in NSF and NIH) has fared quite well relative to many areas of government activity.

IV. CURRENT ROLE OF THE MISSION AGENCIES IN FEDERAL RESEARCH

On the current scene, the mission agencies continue to play dominant roles in many areas of research. Table 2 presents the percentage distribution by agency of federal funds in the major areas of research in FY 1984 (including both basic and applied research). As the table shows, the Defense Department provided nearly 23 percent of all federal funding for physical science research, 50 percent of federal funding for math and computer science research, and almost a third of federal support for psychology. NASA and DOE also support large shares of physical science, environmental science, and engineering research. NSF's shares are smaller. In only one area, environmental sciences, does it support the largest single share of research, and even here its portion is just over one-fourth.

The numbers are somewhat different if one focuses only on basic research, as shown in Table 3, but the overall message is the same: the mission agencies provide the largest share of federal support for most science fields. The only major exception to this is in the life sciences, where a single science agency, NIH, supports by far the largest share of research in biological and medical sciences (75 percent). In many ways, this seems a special case in science policy.

Where the science agencies are most important (and the role of the mission agencies consequently least evident) is in overall support of basic research at universities and colleges, as shown in Table 4. One half of the basic research supported by the federal government is performed at universities and colleges ($3.5 out of $6.9 billion in FY 1984, according to NSF figures). Of this amount, nearly three-fourths (73 percent) is funded by NIH and NSF, and nearly half (49 percent) by NIH alone.

Most of the mission agencies contribute relatively small shares to overall support of academic basic research: Agriculture, 3.5 percent; Energy, 4.9 percent; Defense, 11.3 percent; NASA 4.4 percent; all of the others, less than one percent each. On the other hand, because most of the mission agencies tend to concentrate their support in a limited number of areas, their support is more important in universities and colleges in those fields (e.g., the Department of Agriculture in agricultural research, the Department of Education in education, and NASA in astronomy). Furthermore, these figures do not include support of basic research in federally funded research and development centers (FFRDCs), such as Fermilab, which operate more or less as extensions of academia and are used heavily by academic scientists. This form of operation is particularly important in DOE support of high energy and nuclear physics.

V. TRENDS AND POLICY ISSUES

My observations of the current policy environment suggest a number of trends and issues bearing on research in the mission agencies that

merit the Task Force's attention. Some appear directly in the statement of purpose for these hearings; others underlie it, but are not mentioned explicitly.

A. Funding Levels

The Reagan Administration's science policies have had mixed effects on research in the mission agencies. Despite a period of austerity on the civilian side of the budget, the administration, with the support of the Congress, has gained substantial increases for basic research during the past four years. The science agencies -- NSF and NIH -- have done particularly well, but DOE, NASA and DOD have also recorded real growth in their basic research programs during this period. Table 5 presents the figures (in current dollars, not including the effects of inflation).

At the same time, the administration has sought to reduce funding for applied research, development and demonstration programs in the nondefense agencies on the grounds that such efforts are more appropriate for the private sector. The reductions in applied research programs have been substantial in a number of agencies, including DOE's civilian programs, the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, Interior, and EPA. (The figure for DOE in Table 5 includes nuclear weapons research as well as civilian energy technology.)

These countervailing trends present several concerns:

(1) First of all, the distinction between basic and applied research is not all that clear-cut, and thus these changes may not necessarily produce the intended effects. For example, reductions in NOAA's applied research programs may have significant negative impacts on what many regard as basic research in atmospheric sciences and oceanography. In addition, it seems likely that the administration's different approaches to support of basic and applied research have made the already arbitrary process of classifying these programs for budget reporting even more capricious.

(2) Apart from this, the increase in basic research has been based largely on the belief that it will contribute to economic growth and national security. Without disputing this belief, one might argue that it is equally important for the federal government to support generic applied research efforts as a means of facilitating the utilization of basic knowledge in practical applications. Thus, current policies on basic and applied research may actually be working against one another.

(3) Finally, the reductions in applied research programs may be having negative impacts on institutions (federal laboratories, university research centers, etc.) that are affecting their ability to conduct basic research.

B. Proposed Establishment of a Department of Science

During recent months the notion of establishing a cabinet-level department of science and technology, a seemingly-perennial issue in science policy, has surfaced once again, this time through a recommendation of the President's Commission on Industrial Competitiveness. Although the current version is not likely to gain approval in the near future, it is worth taking note of the issue here because it is closely related to the problems of research in the mission agencies.

Most proposals for creating a science department involve regrouping the R&D functions of various existing agencies. Central to the discussion, therefore, are the relative merits of the current decentralized system of responsibility for R&D, in which most of the mission agencies maintain their own research programs, compared with more centralized systems.

Presumed virtues of centralization include greater efficiency, eliminating duplication of effort, more "clout" for science (based on cabinet status and the ability to speak with a single voice), and (through the joining of science with technology) more rapid application of research results to societal purposes. On the other side of the ledger are (possibly) reducing the effectiveness of research and technology transfer by separating the research from the agency which might apply it; concerns over "placing all of one's eggs in a single basket" for budget purposes; diminished technical capabilities in the mission agencies whose R&D programs are transferred to the new

department; and (of particular concern to the academic science community) loss of the flexibility that comes with multiple points of access and redundancy in potential funding sources.

These pros and cons will bear considerable discussion should the Department of Science and Technology proposal gain serious consideration. The impacts on the mission agencies will need to be understood and treated in the debate.

C. Priorities Among Fields

The problem of setting priorities among fields in research is one that has long occupied the attention of science policymakers. Although a variety of systematic approaches has been proposed, the essential questions of how much to spend on, say, astronomy versus molecular biology are made in a political rather than a scientific manner.

Because of the way in which research budgets are dispersed among the mission agencies, the key priority decisions in research are made in the context of several different agency budgets, with relatively little opportunity for cross-comparisons on the basis of criteria related to science. Basic research in agriculture competes mainly with other agricultural priorities, while high energy physics competes not so much with other areas of science, but with energy programs.

The only Executive Branch units really capable of taking an overview of the basic research system — the Office of Management and Budget and

57-279 O - 87 - 2

the Office of Science and Technology Policy -- affect it mainly at the margins. The diffusion of responsibility for basic research in the Congress means that even if the administration should prepare a budget with carefully weighted choices among fields of science, it would not be likely to receive a coherent legislative review.

Nonetheless, it is worth asking whether the present allocations are optimal, either in terms of the needs of the scientific community or the potential applications to which the research might eventually be put. There may not be a "scientific" way to answer the question of whether biomedical research and high energy physics merit their current levels of support relative to, say, materials science or anthropology, but raising the questions may still be a useful contribution to the political process through which resources for research in both the mission and non-mission agencies are allocated.

D. Responsibility of the Mission Agencies for the Research Infrastructure

Over the past several years, it has become apparent that the infrastructure of U.S. science requires more attention than it has been receiving. The state of science education at all levels, the obsolescence of scientific instrumentation in universities, the condition of academic laboratories and other facilities, the participation of minorities, women and other under-represented groups have all been the subject of study and discussion. All need to be addressed through action.

The problem of facilities, in particular, has given rise to several instances in which universities have sought to obtain funds through

direct intervention in the legislative process, bypassing traditional peer review procedures. In the past, mission agencies played a significant role in the supporting university research facilities, through such efforts as NASA's Sustaining University Program and DOD's Centers of Excellence Program. The continued importance of research in the mission agencies to U.S. science (as discussed earlier in this statement) dictates that solutions to infrastructure problems must involve the mission agencies in more than a token manner. The Committee on Science and Technology is aware of this and the recent legislation on university facilities (HR 2823, Universities Research Facilities Revitalization Act of 1985) introduced by the Chairman deserves support and encouragement.

E. Research Management in the Mission Agencies

The discussion of differences between science-oriented and society-oriented research administration which I presented earlier in this statement suggests some of the continuing tensions which face mission agency research at the operational level. In general, these tensions stem from the researchers' desire for autonomy in their work to pursue the most promising and rewarding avenues from a scientific standpoint, versus the agencies' need to direct the research into areas most relevant to their missions. When managed creatively, these tensions can help stimulate extremely productive work, as is the case in some of the nation's best industrial laboratories. But, when the tensions are manifested in rigid bureaucracies and increasingly confining regulations, the results are antithetical to the conduct of good research.

This is not a new issue, but as I have tried to show, research in the mission agencies is not a new phenomenon. That research is a source of continuing strength for U.S. science and technology and the conditions that help it to flourish need continuing attention. That is why these hearings are so important.

Thank you.

NOTES

(1) W. Henry Lambright, Governing Science and Technology (New York: Oxford University Press, 1976).

(2) National Science Board, Basic Research in the Mission Agencies (Washington, D.C.: U.S. Government Printing Office, 1978). The best-known book on the subject is A. Hunter Dupree, Science in the Federal Government (Cambridge, Mass.: Belknap Press, 1957).

(3) J. Stefan Dupre and Sanford A. Lakoff, Science and the Nation (New Jersey: Prentice-Hall, Inc., 1962)

(4) Vannevar Bush, Science: The Endless Frontier (Washington, D.C.: U.S. Government Printing Office, 1945).

TABLE 1: Overall Budget, Research and R&D Funding Level by Agency, FY 1988
(Budget authority, millions of dollars)

	Overall Budget	R&D	Research	R&D as % of Overall Budget	Research as % of Overall Budget
Agriculture	$31,235	$ 871	$ 839	2.8%	2.7%
Commerce	2,016	358	294	17.8%	14.6%
Defense-Military	258,150	27,337	3,055	10.6%	1.2%
Education	15,423	101	78	0.7%	0.5%
Energy	10,539	4,528	1,864	43.0%	17.7%
HHS	299,428	8,828	4,457	1.6%	1.5%
(NIH)	(8,494)	(8,253)	(3,906)	(94.6%)	(86.9%)
Interior	4,917	358	335	7.3%	6.8%
Transportation	28,594	465	69	1.6%	0.2%
AID	1,316	192	139	14.6%	10.6%
EPA	4,064	260	173	6.4%	4.3%
NASA	7,316	2,822	1,709	38.6%	23.3%
NRC	466	191	191	41.0%	41.0%
NSF	1,328	1,203	1,203	90.6%	90.6%
VA	26,477	193	174	0.7%	0.7%

NOTE: Includes all agencies with more than $100 million in R&D. Figures for R&D and research are for conduct only; facilities are not included.

Source: Office of Management and Budget.

TABLE 2: Percentage Distribution of Research by Agency for Major Fields of Science, FY 1984 (Based on estimated obligations)

	Total	Life Sciences	Psych.	Phys. Sciences	Envir. Sciences	Math/ Computers	Engin.	Social Sciences	Other
Agriculture	5.6	10.2	*	2.3	1.1	2.9	1.5	21.8	-
Commerce	1.9	0.2	0.1	1.7	12.5	3.1	1.0	1.6	3.4
Defense	19.8	4.2	32.6	22.5	16.5	50.2	41.2	0.9	23.8
Education	0.6	0.3	1.1	-	-	-	0.2	11.9	-
Energy	13.7	2.8	-	43.7	7.0	5.4	12.3	1.2	11.6
HHS	29.8	67.7	53.8	3.1	-	2.9	1.2	29.9	51.1
(NIH)	(25.8)	(61.2)	(19.3)	(3.1)	-	(2.8)	(1.2)	(4.2)	(46.5)
Interior	2.7	1.9	-	0.4	11.8	1.3	3.3	0.5	*
Transportation	0.5	0.1	0.2	*	*	0.7	1.7	2.0	0.1
AID	1.1	2.7	-	-	-	0.3	0.1	0.8	1.6
EPA	1.2	1.2	0.3	0.5	3.0	1.0	1.0	2.4	0.6
NASA	11.3	1.0	1.1	13.4	21.4	12.2	25.6	*	0.5
NRC	1.3	-	-	-	-	-	5.4	-	-
NSF	8.2	3.9	5.6	11.6	26.1	18.8	5.0	8.0	6.9
VA	2.0	3.3	4.2	-	-	-	0.1	-	-
Other	0.3	0.5	1.0	0.8	0.6	1.2	0.4	19.0	0.7
TOTAL									
Percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Amount**	$15,108	$5,749	$264	$3,003	$1,279	$446	$3,552	$482	$333

Source: National Science Foundation

* Less than 0.1 Percent
** In millions

TABLE 3: Percentage Distribution of Basic Research by Agency for Major Fields of Science, FY 1984 (Based on estimated obligations)

	Total	Life Sciences	Psych.	Phys. Sciences	Envir. Sciences	Math/ Computers	Engin.	Social Sciences	Other
Agriculture	5.5	8.9	*	2.4	0.8	2.0	2.7	16.6	-
Commerce	0.3	*	*	0.9	-	0.9	0.2	*	-
Defense	11.7	2.8	19.8	11.7	16.8	46.0	33.8	1.3	26.0
Education	0.2	-	-	-	-	-	-	8.3	-
Energy	12.1	1.0	-	39.8	2.1	6.3	10.4	-	1.3
HHS	40.0	78.4	62.8	3.9	-	3.0	3.5	26.0	-
(NIH)	(37.4)	(75.2)	(23.6)	(3.9)	-	(2.9)	(3.5)	(3.7)	49.1
Interior	1.8	0.2	-	0.2	10.2	0.7	5.9	0.3	-
Transportation	*	-	-	-	-	-	*	-	-
AID	*	0.1	-	-	-	*	*	0.3	-
EPA	0.3	0.3	*	0.1	0.6	0.2	0.7	1.7	*
NASA	9.9	0.6	1.8	20.5	16.9	4.6	24.2	0.2	1.0
NSF	16.8	6.5	13.5	19.4	52.0	35.6	18.5	21.0	22.1
VA	0.2	0.4	1.3	-	-	-	-	-	-
Other	1.2	1.1	0.8	1.1	0.6	0.7	0.1	24.3	0.5
TOTAL									
Percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Amount**	$6,981	$3,243	$109	$1,751	$636	$228	$785	$150	$79

Source: National Science Foundation

* Less than 0.1 Percent
** In millions

TABLE 4: Federal Funding for Basic Research at Universities and Colleges, FY 1984 (Estimated obligations, millions of dollars)

	Amount	Percent
Agriculture	$ 120.9	3.5%
Commerce	0.9	*
Defense	395.5	11.3%
Education	4.9	0.1%
Energy	172.4	4.9%
HHS	1,765.5	50.4%
(NIH)	(1,699.4)	(48.5%)
Interior	12.9	0.4%
Transportation	0.2	*
AID	1.7	*
EPA	10.5	0.3%
NASA	155.4	4.4%
NRC	-	-0-
NSF	856.1	24.4%
VA	-	-0-
Other	5.2	0.1%
TOTAL	$3,502.1	99.8%**

Source: National Science Foundation

* Less than 0.1 percent
** Figures do not add to 100% due to rounding

TABLE 5: Federal Funding for Research and Basic Research by Agency, FY 1981 and FY 1985 (Obligations in millions of dollars)

	BASIC RESEARCH			RESEARCH		
	FY 1981	FY 1985	$ Change	FY 1981	FY 1985	$ Change
Agriculture	$ 314	$ 420	33.8%	$ 741	$ 870	17.4%
Commerce	16	18	12.5%	249	220	-11.6%
Defense	604	913	51.2%	2,601	3,319	27.6%
Education	21	14	-33.3%	54	77	42.6%
Energy	586	944	61.1%	1,414	2,213	56.5%
HHS	1,900	2,926	54.0%	3,492	4,605	31.9%
(NIH)	(1,767)	(2,738)	(55.0%)	(2,948)	(4,003)	(35.8%)
Interior	81	103	27.2%	370	351	-5.1%
Transportation	1	0.4	-60.0%	89	80	-10.1%
AID	-	4	-	86	249	189.5%
EPA	11	25	127.2%	218	200	-8.3%
NASA	531	826	55.5%	1,407	1,914	36.0%
NRC	-	-	-	220	168	-23.6%
NSF	897	1,336	48.9%	955	1,414	48.1%
VA	15	15	0	128	175	36.7%
Other	64	94	46.9%	189	179	-5.3%
TOTAL	$5,041	$7,638	51.5%	$12,213	$16,034	31.3%

Source: National Science Foundation

Mr. FUQUA. Thank you.

We will hear from Dr. Lambright now, and then we will have some questions for the two of you.

[A biographical sketch of Dr. Lambright follows:]

DR. W. HENRY LAMBRIGHT

W. Henry Lambright is a professor of Political Science and Public Administration at the Maxwell School, Syracuse University, and director of the Science and Technology Policy Center at Syracuse Research Corporation. Dr. Lambright received his A.B. at Johns Hopkins in 1961, and his M.A. and Ph.D. at Columbia University in 1962 and 1966, respectively. After a year at the Brookings Institution, Dr. Lambright joined the faculty of Maxwell School where he has spent his academic career. He has served as a special assistant with NASA, and consulted for various Federal, State, and local agencies as well as private organizations. Dr. Lambright is a specialist in government as it relates to science, technology, and public policy. He is author of numerous articles and four books, *Governing Science and Technology, Technology Transfer to Cities: Processes of Choice at the Local Level, Educating the Innovative Public Manager,* and *Presidential Management of Science and Technology: The Johnson Presidency.*

STATEMENT OF DR. W. HENRY LAMBRIGHT, PROFESSOR, THE MAXWELL SCHOOL, SYRACUSE UNIVERSITY, AND DIRECTOR, SCIENCE AND TECHNOLOGY POLICY CENTER, SYRACUSE RESEARCH CORP., SYRACUSE, NY

Dr. LAMBRIGHT. Thank you. It is a pleasure to be here, and enjoy my friend Al Teich. Again, I am going to read certain portions of my testimony and summarize the remainder.

At the core of Federal science and technology policy are the Federal laboratories. These often ignored and frequently maligned institutions are one of a number of performers—universities and industry are the primary others—but they are unique in being of the Government. This is true whether they are civil service labs or Government-owned, contractor-operated. They are extensions of Government policy. As such, they provide a technical base of knowledge to the agencies that give them support. They help advise in setting Federal science and technology policies through their agency sponsors; and then they play a large role in implementing those policies as performers of research and development—R&D—and as managers of the work of universities and industry. These are institutions in the middle, and as one would expect of institutions in such a position, they are often subject to various cross-pressures.

Who governs the Federal laboratories? Who influences the direction and pace of their R&D programs? What are the current pressures on and within the laboratories? What are the trends? Where have they been? Where are they headed? In addressing these questions, we will be focusing on the policy issues.

Federal laboratories and Federal policies are supposed to go hand in hand. But sometimes they do not. Federal labs may be part of or extensions of Government, their dominant sponsor. But they also are semiautonomous, frequently as a matter of deliberate design by their creators. They have minds—or policies—of their own. Sometimes such policies are different from Federal policy. This may be good or it may be bad, but it is an inevitable consequence of the size, pluralism, and complexity of the American science and technology enterprise.

The Federal laboratory universe is both huge and diverse. There are more than 700 laboratories in the United States. As noted, these vary greatly in form. Over the years there have been numerous consolidations and even some closings.

A great deal of Federal R&D funds flow to these organizations—approximately one-third. The 1985 Department of Energy, DOE, funding to the 12 multiprogram labs alone was almost $4 billion.

These are usually large institutions, employing sometimes many thousands of people per lab. Oak Ridge National Laboratory, ORNL, alone has almost 5,000 employees, while Lawerence Livermore employs over 7,000. Collectively, the Federal laboratories employ nearly half a million scientists and engineers. Not only are they large in terms of employees, but the Federal laboratories house some of the most expensive and sophisticated scientific equipment in the world.

As to quality, it is natural that this large number includes everything from the outstanding to the mediocre. Among the stronger Federal labs are those that are called national labs. Exactly what makes a national lab different from a Federal laboratory has never been spelled out in any precise way. In the beginning of the 20th century, the National Bureau of Standards, NBS, was established and perhaps pioneered the model. That is, while located under a specific agency, this laboratory had a mission that went beyond that agency and reached to other agencies and the Nation at large. Today, we have many laboratories that have national in their titles: for example, Argonne National Laboratory; Los Alamos National Laboratory, LANL; and National Institutes of Health, NIH. But there are organizations that behave as national institutions which do not have this designation: for example, Jet Propulsion Laboratory, JPL.

The notion of the national laboratory is not just a matter of verbal ornamentation. It reflects a perception, held both inside and ouside the lab, that these institutions are national resources, rather than strictly agency resources. As Congress knows, what people think can be as important as what is where Federal policymaking is concerned. It can affect behavior and the relative independence of national laboratories as compared with other Federal laboratories. The relation of Federal laboratories to Government is somewhat open-ended. Government means other agencies, Congress, and the President. This is because those other institutions see these institutions as separable from agency sponsors—too important to be just the concerns of those agencies.

It is recognized that Federal laboratories, national and otherwise, are crucial to the implementation of U.S. science and technology policies. The fact that these hearings are taking place, in which the Federal labs are a focus of attention, underlines the point. These hearings are the latest of a sequence of studies of the Federal laboratories including one for the White House under David Packard. What is not so well recognized is the fact that these institutions have missions and roles that are self-generated as well as provided to them. Sometimes, the policy signals they get from Government—agency, Congress, President—differ or are slow to develop. Inevitably, there are differences in ends and means among the various players in Federal laboratory policy. Hence, continuity,

change, and conflict take place at different times in the relations between the lab and its policy environment.

In my prepared testimony, I discuss the evolution of the Federal labs in terms of six phases. First, the World II revolution in Federal science and technology policy, 1940–45; second, the atomic energy era, 1945–57; third, the space era, 1957–69; fourth, the era of uncertainty 1969–73; fifth, the energy era, 1973–81; and sixth, the second era of uncertainty, 1981 to the present. These phases bring out differences in emphasis in Federal civil science and technology policy. These represent the major policy shifts for the labs.

Suffice it to say here, in summary, that major labs were born of World War II, and grew after the war, and during the 1950's when atomic energy development was a priority. Other labs were added in the 1960's when space became a national technology mission. After a brief downturn, the shuttle decision and the energy crisis stained many of these newer labs and added to their growth in the 1970's.

I now skip most of the historical parts of the testimony and come to the present time. I will now focus on the contemporary period which I call a second period of uncertainty. This is on page 11 of my prepared testimony.

In 1981, the Reagan administration took office. This coincided with a sharp diminution of the energy threat from OPEC. The Reagan administration decided that energy was no longer a top priority in Federal science and technology. Indeed, the administration sought to dismantle DOE, only to be stopped by Congress. Significantly, however, there was no serious thought given to abandoning the national laboratories under DOE. These would be preserved in part because some of them—for example, LANL, Lawerence Livermore, and Sandia—were primarily weapons labs. Also, all the DOE labs had a great deal of political support and recognized merit independent of DOE. There could be sharp controversy about DOE, in part because of its regulatory responsibilities. But there is relative consensus about the importance of the labs. The big question for a while was where to put them, and one candidate was the Department of Commerce. Nevertheless, with the lessening of funding for energy, the civilian energy labs needed to ask about missions and roles again.

Missions have to do with energy, space, defense, or some other national problem. Role pertains to whether the labs have a place in a given field at all—or should it be the role of the university or industry to be engaged in a particular mission. The Reagan administration, more than any other in the history of labs, raised the question of role, and did so in a way as to narrow considerably what they had been doing. Specifically, it said that the role of the labs was to perform research that was relatively basic and long term, of a high risk character, and work that could not or would not be done by the private sector. This meant that the role of the labs in demonstrations and commercialization was curtailed dramatically, while that in basic research augmented. What the labs were supposed to do about technology development was unclear.

So, the civilian energy labs had a problem of diminished mission and narrowed role in the 1980's. Also, longstanding conflicts with industry and universities reemerged, given a smaller energy R&D

pie to divide. Ironically, the manned space labs of NASA were doing all right in the 1980's as the Reagan administration gave a priority to space R&D it withdrew from energy. The Shuttle was continued and the manned Space Station decision made. Hence, the space labs had relative stability in their environment in terms of mission and role.

The most significant development was with the Department of Defense, DOD. Its R&D funding was growing. This meant that both the NASA and DOE labs could try to obtain support from this source, and some of them did so to avoid layoffs. While manned space missions were doing relatively well, some of the unmanned science satellite programs were not. JPL, which saw some of its programs in this field diminish, looked toward DOD for bolstering.

It was one matter for the NASA labs to supplement their work through DOD, whose own space programs were growing. It was more difficult for the civilian energy laboratories to go in this direction. As a result, a number of the civilian energy labs are shrinking.

What has been happening has been a searching for new missions by the civilian energy labs. This search has been wide ranging, well beyond DOD. For example, ORNL has moved vigorously into disaster work for the Federal Emergency Management Agency and into international energy research for the Agency for International Development. But perhaps the most important, intriguing, and problematic new mission emphasis is economic development.

There is increasing recognition that international competition among high technology nations is creating serious new problems for the United States. The nature of national labs is to relate to national problems. There have been some seminal relationships established. For example, the White House Office of Science and Technology Policy was the principal advocate behind a new national laboratory-steel industry research program that is currently evolving. This is a partnership "in which the steel industry, two national laboratories of DOE, and the NBS are working together to develop 'leap frog' technology to help the steel industry achieve increases in productivity, meet foreign competition, and prepare for the 21st century." Science Advisor Keyworth has explained: "One practical result is to marry the technical expertise of the labs with the needs of the steel industry. The national labs will not do the steel companies' jobs for them; this program provides access for a threatened and important domestic industry to existing taxpayer-supported technical resources" (Alan Schriesheim, "Federal R&D Policy," *Science,* Vol. 226, Nov. 16, 1984; George Keyworth, "Science and Technology Policy: The Next Four Years," *Technology Review,* Feb./Mar. 1984, vol. 88, No. 2).

There is an enormous interest in economic development coming from various States and some local governments. As labs in the early 1970's sought to be relevant to problems of cities and other public service areas, so in the mid-1980's they are groping to find economic linkages with industry and universities at the regional level. It is a fact that in some areas Federal laboratories are the key technical resource. States see this, and are themselves seeking to facilitate relationships for economic development. One new rela-

tionship is taking place along the corridor between ORNL and Knoxville.

A major policy development relevant to lab-industry linkages, and thus economic development, has to do wth patent policies. For years, relations between labs and industry were inhibited by industry fears that Government would take patent property in inventions such relationships might have produced. Now there are changes taking place. For example, in 1980, Congress passed the Bayh-Dole Act, which granted small business firms and not-for-profit organizations greater opportunities to acquire patent rights for federally funded inventions; in 1985, Congress is considering extending the same principles to large business firms. In addition, this year, Congress is discussing the Federal Laboratory Technology Utilization Act, which would allow labs and industry to acquire patents, and share profits based on them.

Yet another instance of Federal labs seeking to do more with industry lies in the broader uses of state-of-the-art machines that are placed in national labs. These are called user facilities, but customarily the primary users were the labs themselves and universities with which they had connections. Now, labs are reaching out and trying to get the attention, interest, and participation of industry in making the most of these user faciliites. An example is Brookhaven National Laboratory's synchrotron light source, where the lab is brokering three-party relationships among itself, universities, and industry. Hopefully, such a relationship at an early point in research will help speed the process by which basic research can be translated into commercially viable products. Also, labs are obliged under the Stevenson-Wydler Act of 1980 to spend 0.5 percent of their funding to transfer developed technology to alternate users, including industry.

Other examples might be found. The point is that there are interesting examples—indeed exemplary cases of—of innovative lab activities that lie in the economic development sphere. These ad hoc activities are taking place because there are national needs and a desire on the part of the labs to find ways to meet them.

These Federal laboratory responses are nevertheless fragmented and ad hoc because there really is no national mission in economic development. There is, of course, no end of debate about industrial policy. Unfortunately, the country has not yet resolved how to translate industrial policy ideas into a national program, and how to relate science and technology, including the Federal labs, to such a derivative mission. Hence, there is activity—much of it significant—but there is little coordination among the labs with respect to these activities. The whole may be less than the sum of the parts.

Conclusions. What lessons can be derived from this review of recent history? One, the story of Federal labs and Federal policy is one of continuity, change, and conflict. The greatest continuity is seen where there is relative consensus as to national need and mission; for example, defense, health research, standards, and measures. Where larger policy consensus is lacking, for example, civilian energy, there is change and conflict.

Two, the major civilian labs in space and energy have experienced an ebb and flow in national priority with respect to their

missions. They have also experienced shifts in political sentiment as to their roles. What should Government do versus what should the private sector do? Today, this is particularly true of the energy labs.

Three, institutions can shrink as their missions decline. But, history shows that missions can go down and then come up again in importance. Space is a classic instance of this ebb-and-flow effect. Hence, there may be need for maintaining institutional strength in the Federal labs, as a buffer against future uncertainties. This can be done only by such labs becoming resilient and adaptive. Diversification as to sponsor and performing appropriate work for others are logical strategies. This has been attempted by many labs.

Four, it is in the nature of multiprogram national labs in particular to respond to national problems, rather than profit opportunities or discipline-based needs. Today, with the relative decline of energy as a mission, there is a particular desire on the part of these labs to deploy to what is perceived as the emerging national need of economic development in those areas where there is strong technological competition from abroad. In the absence of national policy which articulates an R&D strategy as to what is a sensible and legitimate way to go in this area, labs are relating to this need as best they can, ad hoc, usually in a highly individualistic manner.

Five, while the above leads to creative entrepreneurship at the laboratory level, it may also be inefficient, unsuccessful, and even inappropriate. Certainly, it would be better for them to diversify if they did so in the context of a national policy, in which a mission was clear and their role spelled out.

Six, nothing is more obvious than that the laboratories are here to stay. There needs to be more conscious thought given to their care and feeding, for purposes of maintaining vitality and excellence. A clear understanding of how national policy or lack thereof impacts on labs would be in everyone's interest. It may be useful for America to learn lessons about the role of Federal laboratories from other countries that have used them differently than the United States has. Since Japan is a chief competitor in high technology economic development, it is useful to note what it does in terms of national laboratories. In Japan, science and technology policy has been coordinated with industrial policy. Thus, according to a recent study by the Organization for Economic Cooperation and Development, OECD, in Japan:

> R&D programs have been designed to create a technological capability in the key sectors identified by industrial policy as important for the future, and national laboratories, about 20 in number, have been the focal point for catalyzing efforts of universities and firms and disseminating research results (Jean-Eric Aubert, "Innovation Policies—A Three-Way Contrast," *OECD Observer,* Nov. 1984, p. 9).

Obviously, adaptations of foreign institutional approach to the U.S. context would be necessary, assuming that this country deemed the Japanese approach desirable. This would require conscious strategy rather than a piecemeal backing into policy, which now seems to be the case.

Seven, all this comes down, ultimately, to recognizing that the United States has a resource and that this resource—its Federal laboratories—needs to be used effectively. The labs are means,

however, not ends in themselves. Hence, effective use of the Federal labs depends first on having effective national science and technology policies that move with the times. These hearings will hopefully serve to help develop such policies. It is commendable that this congressional committee recognizes the critical interdependence of Federal laboratories and Federal policies.

[The prepared statement of Dr. Lambright follows:]

FEDERAL LABORATORIES AND FEDERAL POLICIES: EVOLUTION AND CURRENT TRENDS

W. Henry Lambright, Professor
The Maxwell School
Syracuse University

and

Director
Science and Technology Policy Center
Syracuse Research Corporation
Syracuse, New York

Testimony before U.S. House Committee on Science and Technology
Science Policy Task Force Hearings
on
Science in the Mission Agencies and Federal Laboratories

October 2, 1985

At the core of federal science and technology policy are the federal laboratories. These often ignored and frequently maligned institutions are one of a number of performers (universities and industry are the primary others), but they are unique in being of the government. This is true whether they are civil service labs or government-owned, contractor-operated. They are extensions of government policy. As such, they provide a technical base of knowledge to the agencies that give them support. They help advise in setting federal science and technology policies through their agency sponsors; and then they play a large role in implementing those policies as performers of research and development (R&D) and as managers of the work of universities and industry. These are institutions in the middle, and as one would expect of institutions in such a position, they are often subject to various cross-pressures.

Who governs the federal laboratories? Who influences the direction and pace of their R&D programs? What are the current pressures on and within the laboratories? What are the trends? Where have they been? Where are they headed? In addressing these questions, we will be focusing on the policy issues.

Federal laboratories and federal policies are supposed to go hand-in-hand. But sometimes they do not. Federal labs may be part of or extensions of government, their dominant sponsor. But they also are semi-autonomous, frequently as a matter of deliberate design by their creators. They have minds--or policies--of their

own. Sometimes such policies are different from federal policy. This may be good or it may be bad, but it is an inevitable consequence of the size, pluralism, and complexity of the American science and technology enterprise.

The Nature of Federal Laboratories

The federal laboratory universe is both huge and diverse. There are more than 700 laboratories in the United States. As noted, these vary greatly in form. Over the years there have been numerous consolidations and even some closings. There were once over 1000 federal laboratories.

A great deal of federal R&D funds flow to these organizations--approximately one-third (Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel, Vol. 1, Summary Report, July 1984). The 1985 Department of Energy (DOE) funding to the 12 multiprogram labs alone was almost $4 billion.

These are usually large institutions, employing sometimes many thousands of people per lab. Oak Ridge National Laboratory (ORNL) alone has almost 5000 employees, while Lawrence Livermore employs over 7000. Collectively, the federal laboratories employ nearly half a million scientists and engineers.

Not only are they large in terms of employees, but the federal laboratories house some of the most expensive and sophisticated scientific equipment in the world: high-voltage electron microscopes, synchrotrons, complex computer equipment, satellite microprocessors, telescopes, atomic resolution microscopes, proton accelerators, and other frontier tools. Often, scientific experiments can only be performed when a particular combination of equipment--sometimes large and expensive--is available in one location. Many of the federal labs contain these unique and necessary combinations of equipment. For example, at ORNL, the close proximity of a 30-meter, small-angle neutron scattering instrument and a companion 10-meter, small-angle X-ray scattering instrument to compare results is extremely important in many areas of polymer chemistry.

As to quality, it is natural that this large number includes everything from the outstanding to the mediocre. Among the stronger federal labs are those that are called "national labs." Exactly what makes a national lab different from a federal laboratory has never been spelled out in any precise way. In the beginning of the 20th century, the National Bureau of Standards (NBS) was established and perhaps pioneered the model.

That is, while located under a specific agency, this laboratory had a mission that went beyond that agency and reached to other agencies and the nation-at-large. Today, we have many laboratories that have "national" in their titles: e.g., Argonne National Laboratory; Los Alamos National Laboratory (LANL); and National Institutes of

Health (NIH). But there are organizations that behave as "national" institutions which do not have this designation: e.g., Jet Propulsion Laboratory (JPL).

The notion of the "national laboratory" is not just a matter of verbal ornamentation. It reflects a perception, held both inside and outside the lab, that these institutions are national resources, rather than strictly agency resources. As Congress knows, what people think can be as important as what is, where federal policy-making is concerned. It can affect behavior and the relative independence of national laboratories as compared with other federal laboratories. The relation of federal laboratories to government is somewhat open-ended. Government means more than the dominant agency to which labs report. Government means other agencies, Congress, and the President. This is because those other institutions see these institutions as separable from agency sponsors--too important to be just the concerns of those agencies.

It is recognized that federal laboratories ("national" and otherwise) are crucial to the implementation of U.S. science and technology policies. The fact that these hearings are taking place, in which the federal labs are a focus of attention, underlines the point. These hearings are the latest of a sequence of studies of the federal laboratories including one for the White House under David Packard. What is not so well recognized is the fact that these institutions have missions and roles that are self-generated as well as provided to them. Sometimes, the policy signals they get from government--agency, Congress, President--differ or are slow to

develop. Inevitably, there are differences in ends and means among the various players in federal laboratory policy. Hence, continuity, change, and conflict take place at different times in the relations between the lab and its policy environment.

Evolution of Federal Laboratories and Federal Policies

These issues can be placed in better relief by outlining the evolution of federal laboratories and federal policy. In doing so, we will emphasize change and conflict. Amidst change and conflict, there has been much continuity, as in the case of NBS, NIH, and most Defense Department labs. There has been more turbulence in connection with space and energy labs. The labs associated with this area of policy--especially the civilian energy labs--have been the ones that have been at the heart of the recent controversy.

It is useful to discuss the evolution of federal labs and federal policy in terms of six phases: (1) the World War II "revolution" in federal science and technology policy, 1940-1945; (2) the atomic energy era, 1945-1957; (3) the space era, 1957-1969; (4) the era of uncertainty 1969-1973; (5) the energy era 1973-1981; and (6) the second era of uncertainty, 1981-present. These phases bring out differences in emphasis in federal civil science and technology policy. These represent the major policy shifts for the labs.

World War II and the Revolution in Federal Science and Technology Policy, 1940-1945

Before World War II, most federal science and technology was carried out in federal laboratories or in university laboratories related to the Department of Agriculture. Agriculture was in fact the dominant civil science agency. But funding was small--$50 million--and few science and technology issues gained the attention of federal policymakers.

World War II changed all this. The U.S. began spending billions, and doing so in institutions only loosely connected with government. America created the "contract" state, wedding industry and universities to federal R&D, and making science and technology a major subject on the agenda of federal decision makers.

The Atomic Energy Era, 1945-1957

What was created by the war were a number of new laboratories that sought to link science with technology. These were more than research institutions; they were what some have called technology development organizations. Their objective was to create new capabilities that for one reason or another could not be created by universities and industry. These capabilities required special equipment, organized teams of scientists and engineers from a range of disciplines, and often entailed a measure of hazard, as well as national security considerations.

Atomic energy obviously was the premier new capability to be developed. Further work had to be accomplished with bombs: first the atom bomb, then the hydrogen bomb. In addition, work went into reactors to power first ships and then civilian electric plants. Federal policy, such as Eisenhower's atoms for peace program in 1953 and the rewriting of the atomic energy act in 1954, encouraged the laboratories created by the war in this civilian direction. The labs were called national labs and in fact had their origins before the agency under which they were placed--Atomic Energy Commission (AEC).

By the late 1950s, this mission of civilian nuclear power had become a large enterprise for various AEC labs, one they wished to continue indefinitely. As various light water reactor designs moved from R&D to commercialization under industry in the 1960s, the labs looked to the next generation of technology. This was defined as the liquid metal fast breeder reactor (LMFBR). For the atomic energy labs, there was a measure of continuity. They had become accustomed to a certain style of work--"big science," organized around big programs and large-scale, long-term missions. LMFBR, however, could not absorb all the national lab talents in the 1960s that had been built up in the 1950s. So, in some AEC labs, there was a beginning at diversification. However, in the 1960s, the more significant changes in federal policy affecting federal labs were not in atomic energy at all. They were in space.

The Space Era, 1957-1969

Sputnik ushered in the space era for federal policy and federal labs. Again, as with atomic energy, the labs preceded the agency, National Aeronautical Space Administration (NASA), which was created in 1958. The institutional core of NASA was a group of aeronautical laboratories inherited from the National Advisory Committee for Aeronautics (NACA). Also placed under NASA's jurisdiction was the rocket laboratory, headed by Wernher von Braun, formerly under the U.S. Army at Huntsville, Alabama. Also moved under NASA was JPL. Finally, NASA created some additional labs (e.g., Manned Spacecraft Center in Texas and Electronics Research Center in Massachusetts).

These vast changes reflected the new space mission. This mission also meant a change in style. The old NACA aeronautical labs largely did work in-house. The NASA style was to do some work in-house, but also to use labs to help manage huge contracts with industry.

While America was going to the moon, the big NASA labs did well. This was because their missions matched what their agency wanted to do and what the nation--through Congress and the President--wanted. As with the nuclear labs, space involved a very large-scale technology mission that matched the scale of the labs themselves. These were "big science" organizations. They used large-scale equipment

and they mobilized large numbers of scientists and engineers around big technical problems associated with these missions. There was a synergism.

But by 1969, the juxtaposition of federal policy, agency, and labs was coming uncoupled. The country was losing interest in space, and nuclear energy was becoming a target of environmentalist critics. Science and especially technology were in trouble, seen as problems rather than solutions.

An Era of Uncertainty, 1969-1973

There was continuity in space and energy in this next era, 1969-73. But, there were change and conflict also. For both the space and atomic energy labs, there were substantial cutbacks and doubts about the future. The mainline civilian missions--nuclear reactors and manned space--were in trouble.

There was much talk about redeployment and "work-for-others." The Electronics Research Center was in fact killed as a NASA lab, only to be revived and restaffed as a Department of Transportation lab. There was talk and some effort to use aerospace specialists in other domestic areas--technology transfer to state and local government was particularly in vogue at this time. The Nixon Administration spoke of a New Technology Opportunities Program.

But, these domestic missions simply were not well enough funded to absorb the large-scale enterprises. Having created huge, mission-oriented science and technology installations, there was a need to find huge missions on which they could work. For the space labs, the uncertainty, lay-offs, and underemployment came to an end in 1972, with the national decision to build a Shuttle. For the atomic energy labs, it came to an end with the energy crisis, beginning in 1973. For NASA, there was continuity in mission. For the nuclear labs, however, there was change.

The Energy Era, 1973-1981

While manned space began coming back in the 1970s, it was energy that was the dominant civil science and technology mission. Between FY 1974 and FY 1977, space expenditures remained relatively constant at about $2.7 billion, while energy funding soared from $1.1 billion to $2.8 billion. This represented a greater than 100 percent increase for energy.

As a consequence, many of the NASA labs got into the energy business--a wind-power, for example. This was indicative of the change in energy R&D--from nuclear to energy-in-general. AEC gave way to the Energy Research and Development Administration (ERDA) in 1975; and ERDA in turn was subsumed by DOE in 1977. The labs continued as these reorganizations in Washington took place. However, they broadened and grew, and diversified into solar, wind, fossil fuels, fusion, and various other areas. Even the weapons labs, such as LANL, became quite a significant force in certain alternative energy

sources, notably solar energy. And, in 1975, a new laboratory which focused on solar, Solar Energy Research Institute, was created. In some ways this stood as a symbol of the nation's long-term investment in an alternative to nuclear and fossil fuel resources.

During the mid and late 1970s, therefore, energy R&D loomed large, even as nuclear R&D (and particularly the LMFBR program) diminished in priority. Labs found plenty to do on energy. After President Carter proclaimed a national synthetic fuels goal in 1979, the future seemed relatively certain and secure for the energy labs. So persuaded was everyone that energy-in-general was going to be the "big science" mission for a long time to come that NASA began actively promoting multi-billion dollar energy systems from space.

A Second Period of Uncertainty, 1981-Present

In 1981, the Reagan Administration took office. This coincided with a sharp diminution of the energy threat from OPEC. The Reagan Administration decided that energy was no longer a top priority in federal science and technology. Indeed, the Administration sought to dismantle DOE, only to be stopped by Congress. Significantly, however, there was no serious thought given to abandoning the national laboratories under DOE. These would be preserved in part because some of them--e.g., LANL, Lawrence Livermore, and Sandia--were primarily weapons labs. Also, all the DOE labs had a great deal of political support and recognized merit independent of DOE. There could be sharp controversy about DOE, in part because of its regulatory responsibilities. But there is relative consensus about

the importance of the labs. The big question for a while was where to put them, and one candidate was the Department of Commerce. Nevertheless, with the lessening of funding for energy, the civilian energy labs needed to ask about missions and roles again.

Missions have to do with energy, space, defense, or some other national problem. Role pertains to whether the labs have a place in a given field at all--or should it be the role of the university or industry to be engaged in a particular mission. The Reagan Administration, more than any other in the history of labs, raised the question of role, and did so in a way as to narrow considerably what they had been doing. Specifically, it said that the role of the labs was to perform research that was relatively basic and long-term, of a high risk character, and work that could not or would not be done by the private sector. This meant that the role of the labs in demonstrations and commercialization was curtailed dramatically, while that in basic research augmented. What the labs were supposed to do about technology development was unclear.

So, the civilian energy labs had a problem of diminished mission and narrowed role in the 1980s. Also, longstanding conflicts with industry and universities reemerged, given a smaller energy R&D pie to divide.

Ironically, the manned space labs of NASA were doing all right in the 1980s as the Reagan Administration gave a priority to space R&D it withdrew from energy. The Shuttle was continued and the Manned Space Station decision made. Hence, the space labs had relative stability in their environment in terms of mission and role.

The most significant development was with the Department of Defense (DOD). Its R&D funding was growing. This meant that both the NASA and DOE labs could try to obtain support from this source, and some of them did so to avoid lay-offs. While manned space missions were doing relatively well, some of the unmanned science satellite programs were not. JPL, which saw some of its programs in this field diminish, looked toward DOD for bolstering.

It was one matter for the NASA labs to supplement their work through DOD, whose own space programs were growing. It was more difficult for the civilian energy laboratories to go in this direction. As a result, a number of the civilian energy labs are shrinking.

What has been happening has been a searching for new missions by the civilian energy labs. This search has been wide-ranging, well beyond DOD. For example, ORNL has moved vigorously into disaster work for the Federal Emergency Management Agency and into international energy research for the Agency for International Development. But perhaps the most important, intriguing, and problematic new mission emphasis is economic development.

There is increasing recognition that international competition among high technology nations is creating serious new problems for the U.S. The nature of national labs is to relate to national problems. There have been some seminal relationships established. For example:

* The White House Office of Science and Technology Policy was the principal advocate behind a new national laboratory-steel industry research program that is currently evolving. This is a partnership "in which the steel industry, two national laboratories of DOE, and the NBS are working together to develop 'leap frog' technology to help the steel industry achieve increases in productivity, meet foreign competition, and prepare for the 21st century." Science Adviser Keyworth has explained: "One practical result is to marry the technical expertise of the labs with the needs of the steel industry. The national labs will not do the steel companies' jobs for them; this program provides access for a threatened and important domestic industry to existing taxpayer-supported technical resources" (Alan Schriesheim, "Federal R&D Policy, Science, Vol. 226, Nov. 16, 1984; George Keyworth, "Science and Technology Policy: The Next Four Years," Technology Review, Feb./Mar. 1984, Vol. 88, No. 2).

* There is an enormous interest in economic development coming from various states and some local governments. As labs in the early 1970s sought to be relevant to problems of cities and other public service areas, so in the mid-1980s they are

groping to find economic linkages with industry and universities at the regional level. It is a fact that in some areas federal laboratories are the key technical resource. States see this, and are themselves seeking to facilitate relationships for economic development. One new relationship is taking place along the corridor between ORNL and Knoxville.

* A major policy development relevant to lab-industry linkages, and thus economic development, has to do with patent policies. For years, relations between labs and industry were inhibited by industry fears that government would take patent property in inventions such relationships might have produced. Now there are changes taking place. For example, in 1980, Congress passed the Bayh-Dole Act, which granted small business firms and not-for-profit organizations greater opportunities to acquire patent rights for federally funded inventions; in 1985, Congress is considering extending the same principles to large business firms. In addition, this year, Congress is discussing the Federal Laboratory Technology Utilization Act, which would allow labs and industry to acquire patents, and share profits based on them.

* Yet another instance of federal labs seeking to do more with industry lies in the broader uses of state-of-the-art machines that are placed in national labs. These are called "user facilities," but customarily the primary users were the labs themselves and universities with which they had connec-

tions. Now, labs are reaching out and trying to get the attention, interest, and participation of industry in making the most of these user facilities. An example is Brookhaven National Laboratory's synchrotron light source, where the lab is brokering three-party relationships among itself, universities, and industry. Hopefully, such a relationship at an early point in research will help speed the process by which basic research can be translated into commercially viable products. Also, labs are obliged under the Stevenson-Wydler Act of 1980 to spend .5 percent of their funding to transfer developed technology to alternate users, including industry.

Other examples might be found. The point is that there are interesting examples--indeed exemplary cases--of innovative lab activities that lie in the economic development sphere. These ad hoc activities are taking place because there are national needs and a desire on the part of the labs to find ways to meet them.

These federal laboratory responses are nevertheless fragmented and ad hoc because there really is no national mission in economic development. There is, of course, no end of debate about industrial policy. Unfortunately, the country has not yet resolved how to translate industrial policy ideas into a national program and how to relate science and technology, including the federal labs, to such a derivative mission. Hence, there is activity--much of it significant--but there is little coordination among the labs with respect to these activities. The whole may be less than the sum of the parts.

57-279 O - 87 - 3

Conclusions

What lessons can be derived from this review of recent history?

1. The story of federal labs and federal policy is one of continuity, change, and conflict. The greatest continuity is seen where there is relative consensus as to national need and mission (e.g., defense, health research, standards and measures). Where larger policy consensus is lacking (e.g., civilian energy) there is change and conflict.

2. The major civilian labs in space and energy have experienced an ebb and flow in national priority with respect to their missions. They have also experienced shifts in political sentiment as to their roles: What should government do versus what should the private sector do? Today, this is particularly true of the energy labs.

3. Institutions can shrink as their missions decline. But, history shows that missions can go down and then come up again in importance. Space is a classic instance of this ebb and flow effect. Hence, there may be need for maintaining institutional strength in federal labs, as a buffer against future uncertainties. This can be done only by such labs becoming resilient and adaptive. Diversifica-

tion as to sponsor and performing appropriate "work for others" are logical strategies. This has been attempted by many labs.

4. It is in the nature of multiprogram national labs in particular to respond to national problems (rather than profit opportunities or discipline-based needs). Today, with the relative decline of energy as a mission, there is a particular desire on the part of these labs to deploy to what is perceived as the emerging national need of economic development in those areas where there is strong technological competition from abroad. In the absence of national policy which articulates an R&D strategy as to what is a sensible and legitimate way to go in this area, labs are relating to this need as best they can, ad hoc, usually in a highly individualistic manner.

5. While the above leads to creative entrepreneurship at the laboratory level, it may also be inefficient, unsuccessful, and even inappropriate. Certainly, it would be better for them to diversify if they did so in the context of a national policy, in which a mission was clear and their role spelled-out.

6. Nothing is more obvious than that the laboratories are here to stay. There needs to be more conscious thought given to their care and feeding, for purposes of maintaining vitality and excellence. A clear understanding of how

national policy (or lack thereof) impacts on labs would be in everyone's interest. It may be useful for America to learn lessons about the role of federal laboratories from other countries that have used them differently than the U.S. has. Since Japan is a chief competitor in high technology economic development, it is useful to note what it does in terms of national laboratories. In Japan, science and technology policy has been coordinated with industrial policy. Thus, according to a recent study by the Organisation for Economic Cooperation and Development (OECD), in Japan:

> R&D programs have been designed to create a technological capability in the key sectors identified by industrial policy as important for the future, and national laboratories (about 20 in number) have been the focal point for catalyzing efforts of universities and firms and disseminating research results (Jean-Eric Aubert, "Innovation Policies--A Three-Way Contrast," OECD Observer, Nov. 1984, p. 9).

Obviously, adaptations of foreign institutional approach to the U.S. context would be necessary, assuming that this country deemed the Japanese approach desirable. This would require conscious strategy rather than a piecemeal backing into policy, which now seems to be the case.

7. All this comes down, ultimately, to recognizing that the United States has a resource and that this resource--its federal laboratories--needs to be used effectively. The labs are means, however, not ends in themselves. Hence, effective use of the federal labs depends first on having effective national science and technology policies that move with the times. These hearings will hopefully serve to help develop such policies. It is commendable that this congressional committee recognizes the critical interdependence of federal laboratories and federal policies.

Mr. FUQUA. Thank you very much, Dr. Lambright.

In the closing part of your statement you were talking about national labs had to be resilient to keep up with the changing times when we have the ups and downs of what is vogue today is not tomorrow.

How do you keep good researchers interested in that, if you have someone working in energy, and the lab director comes in today and says, "I am sorry, that is not high priority today, you are going to do something else. We are taking a lot of your money away because Congress and OMB and the administration has changed policies"? What happens to that person; how do they sustain after that what they have been involved in for a long time, very devotedly, and then come back a year or two later and say today we need to get you back on the project you were working on?

Dr. LAMBRIGHT. There is a famous book that came out some years ago that talked about an organization called "Exit Voice" and it was essentially a response to decline. How do institutions and people respond to decline or problems in their environment? One is to exit, leave. A man can essentially say, "I am not an energy man, and I am going. I cannot live with the change, I am therefore going to leave this laboratory and go to another and do that."

A voice. A voice means protests. He tries to change the mind of the superior, he tries to say that energy is important and that we should try harder to say in this business.

Loyalty is one where the man goes along with the directive from his superior. Where you are loyal to your organizational superior, and you are forced to change, you sometimes do. You nevertheless must have work that is interesting to stay on the peak of your field and so the dilemma is really with those individuals who choose to stay and are moving into different areas.

If they have another mission area to move into, that keeps them excited, that is equally challenging, it is all well and good. But more often than not, it isn't easy to move into new areas, so that individuals retreat to an individual kind of research. That might be down in universities where an individual professor does his own thing and where you hope they are doing mission-oriented work.

If there is an alternate mission for that man who stays in the lab to work on, he will retreat to doing individualistic kind of projects which may be interesting to him but do not necessarily serve the country's interests, and which might be more appropriate to the university than to a national laboratory.

Therefore, what I am essentially saying is for those individuals who choose to stay, the answer to keeping resilient is having another applied mission equally interesting and important to that man.

Dr. TEICH. If I may add just a small bit to that, the problem doesn't always arise quite that directly. There may often be sciences, as you know, where research in a given area may be applicable to others. One is photovoltaics, which of course were developed in NASA laboratories. A considerable amount of work was done on them in NASA laboratories in the period when space research was

a high priority mission and one of Dr. Lambright's historical periods, and which subsequently found a great deal of applicability to energy, alternative energy research. So that a given piece of research can be applied to more than a single mission and one of the strengths I think of many of our Federal laboratories is their ability to do work that can be applicable to different missions. And I think that one of the things we need to take a better advantage of are the synergisms between different areas of research and the applications of given areas to more than one national mission.

Mr. FUQUA. What should be the criteria for reorganizing the present laboratories or creating new ones?

Dr. LAMBRIGHT. What should be the criteria?

Mr. FUQUA. For reorganizing present—going back to the Packard Commission, which was also initiated somewhat by the urging of this committee of the role and scope of national laboratories, so that with limited funds, we did not have laboratories because they are running out of projects trying to compete against others. Or for instance, there was one of the laboratories that was doing extensive work in forestry. Every land grant college in the country has a forestry school. It didn't seem really appropriate for that energy lab to be involved in forestry. How do we make sure that they do not compete against what can legitimately be done in colleges and universities and at the same time provide the resources that the Government needs? Should there be any reorganization, and what should be the criteria for them?

We have had one laboratory right now in dire straits because they ran out of work. They worked themselves out of a job and they are hurting now. They are scrambling trying to find things that they can do to keep their team going.

Dr. LAMBRIGHT. Well, I think that the answer to that question is if one looks for an answer by examining the record, history, which is the best way of trying to think about a question like that, the country has had ups and downs in missions in the past where there essentially has been underemployment of laboratories and the country has had to address the question in the past.

So what has been some of the criteria that have been employed in the past for this same issue? I remember—I am sure Al does, too—in the era of the late sixties when NASA had its peak and was beginning to go down. There was a serious question: "Do you need all of these laboratories, NASA? Do you need all of them? Should we get rid of some of these labs? Can you reorganize them and go move some of these to new missions?"

NASA made the point that certain laboratories were absolutely core to its mission and that these had to be maintained as Government institutions because not only did they do work but they also helped provide the technical expertise to the agency which it needed to govern industry and the universities. So it drew the line.

It could not draw the line at certain other institutions and I recall one laboratory, one called the Electronics Research Laboratory, which had been set up on Boston, MA, where it was argued that this was no longer as necessary to NASA as it might have been in another era. The question then was what was to be done with this surplus institution and was there another mission to which you can deploy this electronics research institution?

It happened there was another mission coming up and the mission was the Department of Transportation. It made the argument. "We, like NASA, not only had to do research, we need a technical expertise that we can depend on that is of the Government and therefore we need a laboratory that will provide that expertise." There had therefore to be a genuine redeployment of institutions there from one agency to the next. It was canceled as a NASA lab, and it was then redeployed to a Department of Transportation lab.

The criteria, however, were more complicated than simply shifting one to the other, because in effect when you moved one lab from a declining mission to a mission environment that was coming up, you had a mismatch. In effect, the laboratory employed high space technical engineers. The people needed in the Department of Transportation were different kinds of engineers. So gradually over time, the laboratory took the shape of its new parent, which was the Department of Transportation.

In effect the criteria in this instance were if there was a mission available and if there is a mission, is there enough match that you can move the lab to the next mission, and if there isn't, do you have to make changes in the lab in terms of employment. That was in effect done. If you move that to the present era, you would have to ask, if you have laboratories that are declining, is there another Government agency with a mission that can go up, and that needs a capability?

If the answer is yes, then you will retain—it is easier to change, it is easier to keep a laboratory and change it than to create a whole one from scratch. But if there isn't, then I think you have to entertain questions that you don't like to entertain. Do you cancel or terminate certain institutions? If there had not been a Department of Transportation available for the Electronics Research Laboratory, it seems to me that an appropriate policy decision might have been to have terminated it and to let some of the work go to industry and the universities at this point in history.

Mr. FUQUA. Mr. Brown.

Mr. BROWN. Gentlemen, let me ask just one question dealing with how we can better organize and manage this tremendous resource which staggers the imagination almost, particularly if one is not involved in it. Didn't one of you mention a figure of $4 billion just for the Defense Department?

Dr. LAMBRIGHT. Just for the national labs under DOE.

Mr. BROWN. And the total for all the national labs is what? Can you offer an estimate?

Dr. LAMBRIGHT. I had one-third of the Federal R&D.

Mr. BROWN. One-third would be about?

Dr. LAMBRIGHT. All the labs?

Mr. BROWN. Seventeen billion dollars or something like that. Which is a very large resource and involves what, 50,000, 100,000 people or something of that sort?

The question emerges of how do you manage this system in such a way as to get the maximum national benefit, particularly considering this phenomena of ebb and flow and change in mission and so on, which is now handled pretty much on ad hoc basis. I remember when JPL went through the trauma of a reduced space mission and they had to look for other missions, they went to DOD, a rea-

sonable place to go. But I think they did this more or less on their own, looking for what were the most compatible programs to utilize the resources that they had there, and they are to be commended for doing that, but it produced some transitional change in personnel at the same time.

In this committee, we have kicked around the idea from time to time of establishing an organization to deal with the problems of technology management and development, something paralleling the National Science Foundation, for basic research, but dealing more with the problems of technology base and economic development, and I am wondering if that kind of concept could be refined to include establishing a structure of that sort with a major role in terms of just keeping on top of the national laboratory resources and helping it to define missions, realign missions, to identify priorities, and to refocus it in a new area when it was necessary to do so.

We have, for example, a growing need for materials research and we are funding materials laboratory development now. I am not sure we are doing that in a coordinated way. As a matter of fact, both the executive branch and Congress probably could use some better tools than we have for making that kind of a determination.

Dr. LAMBRIGHT. I think what you are saying is correct. What I have observed is that there is a great deal going on at the laboratory level reaching out for, say, a mission like economic development. It is very ad hoc and entrepreneural. Much of it is taking place in connection with State government, which is I think a very good development. The national policy has been relatively permissive with respect to what the labs do.

Mr. BROWN. Let me give you one other example—the steel initiative—which apparently originated in the executive office and which is a very commendable initiative. It was responsive to a lot of demands here in Congress to do something for the steel industry. They have conceived a plan which I think is reasonable, to involve several of the national labs in partnership with the steel industry and other institutions, I presume, to do something about making some breakthrough developments in steel.

Would it not have been better if we had had some sort of an institutional structure which could have identified a pressing problem like this, and made the recommendations to the White House or to Congress, that we ought to do something of this sort, and to deal with other problems? There are other things than steel that we are concerned about.

Dr. LAMBRIGHT. My answer is absolutely yes, and I think that this comes up over and over again and 8 times out of 10 opportunities are missed because there is no structure to deal with this.

Mr. BROWN. There is a little incoherence in philosophy also, which makes it difficult to deal with some of these problems.

Dr. LAMBRIGHT. It basically is a market approach we are using with respect to the labs in the sense of their initiative. The labs go where they can. If a lab sees layoffs coming, it then seeks out support from the Department of Defense or wherever it can get support to avoid layoffs.

Mr. BROWN. But a lab couldn't come up with something like a steel initiative because that involves a policy decision that goes far beyond the laboratory itself.

Dr. LAMBRIGHT. What the lab can do easily is move into areas that are an extension of what it already does, more or less. What the lab can't do is make a radical jump into a totally new relationship involving real change.

Dr. TEICH. May I speak to that?

Mr. BROWN. Yes.

Dr. TEICH. I think you have put your finger on it, phrasing this question on an important aspect of it, and that is the notion that we have a national system of laboratories and very seldom do we really think in terms of these laboratories as a system, which I think more as with terms of the laboratories of each agency—of the DOE laboratories, or EPA, or Department of Defense, and so on. That is characteristic, of course, of the way the Government is organized, and it is important at one level to maintain that kind of structure, because the laboratories do have important missions which need to be served and that is, in most cases, their essential and first priority.

I think by conceptualizing, viewing these institutions as a system, and establishing some kind of a structure which can make use of them in a coordinated way, without detracting from their ongoing missions, but on top of it essentially, I think we could accomplish a great deal in the steel industry initiative, or similarly, I guess that would serve such national needs that are being served, otherwise it is a very good example.

We need to set up a structure that could take advantage of the commonalities of laboratories, that can view them overall as a resource and within the pluralism, without trying to bring them all under a single roof, can employ the pluralism of resources in a coordinated way.

Mr. BROWN. Of course, we have to be careful at the same time that we don't create a rigid, centralized system of control that threatens the relationship between the mission agency and the individual labs, and in the same way, that we have to be concerned that the NSF doesn't exercise some autocratic control over the way basic research is conducted around the country.

Dr. LAMBRIGHT. What we are saying is that you need a supplement to what exists that is in everyone's interests in effect. We have to assume there will be an ebb and flow and history shows us this is the case. Therefore, when you have the shifts in a situation, when national policies change and you have these institutions and you have a mismatch, if you do not act to make adjustments, what will happen will be inefficiencies, layoffs, the loss of talented people, and the country will not get its best from this particular resource.

Mr. BROWN. I remember the frustration that the chairman of the Appropriations Committee expressed several years ago about these multitudinal national labs. There were 800 at that time. Nobody could tell him how many there were, what they were doing or anything else. He did apparently authorize a special Appropriations Committee study to ferret out all of what was going on in the Federal laboratory system, in order to be able to do a more intelligent

job of making policy at the level of the Appropriations Committee. I am not sure he succeeded, but it reflected the lack of any central source of even information about all of the activities of the Federal laboratories at that time.

Dr. LAMBRIGHT. It would help individual laboratories just simply to know what other laboratories are doing in terms of these economic development initiatives with the States.

Mr. BROWN. Mr. Ritter.

Mr. RITTER. Thank you, Professor Brown. I think you have made some very salient points.

I would like to thank our two witnesses. I think that they have given us the kind of background to deal with the problem, which is right here, it is right now. There is I believe something we can do about it. It is not one of these problems that are so long range, so far out of the jurisdiction we can't come up with potential policy solutions.

You know the Democrats to some extent have defined this realm of industrial policy. The Republicans have talked about industrial competitiveness. To some extent, policy from the Democratic perspective has to have some hierarchy of decision power and to some extent, the Republican response on industrial competitiveness has been to create a complement for innovation and invention. But I must say, that in this arena, there may well be some shared common ground, shared ways of going about it. There is still a real opportunity given this area of uncertainty, as you mentioned.

Then the question becomes, given the complexity of all of these different institutions—there are far reaching geographic, political constituencies—the question then becomes under what Federal policy aegis does this reorientation take place? And if orientation is defined by a desire to integrate a little industrial policy with creating the climate for industrial competitiveness, therefore, the necessity for involving a very high degree of private sector input, industry input, how do you foresee a scenario like that taking place? What is the relevant Government agency? Is it OSTP; is it OMB; is it some mega-mission agency? Somewhere, somehow, somebody has to have the opportunities for this if it is going to happen.

Dr. LAMBRIGHT. Well, I think that because of the fact that labs are under—the organization of the Government is such that labs are essentially underneath agencies, and agencies are very jealous of their labs. Even if a laboratory may be in the state of decline, there is the fear that another agency may grab some of its best people that are in that particular lab to work on its projects.

So it seems to me if you are talking about a system where you have an initiative and a system that can relate these laboratories to new missions, and if industrial policy or industrial competitiveness is the new mission, how could you relate this resource to the new mission, you are talking about something where it seems to me there is a top management need or strategic management need.

I would say it has to come from the White House. It has to come from OSTP and OMB. There is no other agency that exists that really can handle this particular problem that you are talking about right now. If you want to create a new agency, a brand new organization in the system, with a great deal of power to effect the policies of other agencies, that would be possible, but at the

moment, such a super-agency doesn't really exist, so therefore, you would have to do it through the OMB and through the OSTP and there is no reason why committees couldn't be constructed to advise the OSTP, which would include industrial representatives.

Mr. RITTER. How defined is the mission of the individual laboratory by rule, regulation, or legislation in terms of enabling agreements, how rigid are they?

Dr. TEICH. I think obviously that is a question you will have plenty of witnesses in the upcoming days that will have better answers than either of us, but it seems to me it varies considerably among the agencies. Some of the laboratories, as far as I know, are not defined at all in legislation and exist simply as a matter of having been created by the agencies and have a legal existence that isn't characterized by any very rigid sets of rules that exist at the laboratories, at the agencies' discretion.

Mr. RITTER. The agencies have a fairly rigid set——

Dr. TEICH. Agencies have of course their missions and I think there has been an effort in recent months to define more carefully the missions, particularly of the larger laboratories, as a management tool, in connection with the aftermath of the Packard report, to tell more specifically what each of the laboratories is supposed to do and have some measure of evaluating whether it is accomplishing its goal.

Mr. RITTER. OSTP, if I may interject, OSTP does not have the overriding clout to get some of these changes made. We saw what happened with the steel initiative. I am not criticizing it, there was natural competition between the agencies involved and the OSTP. If you wanted to do this in the way that George Brown was talking about, you would really need some kind of enabling legislation, rule or regulation, to give OSTP some of this authority.

Mr. BROWN. Would you yield?

Of course, the OSTP has been a strong proponent of some kind of structure, a departmental structure, for science and technology within which this could reasonably fit. Although there is no assurances that that will be recommended by the——

Mr. RITTER. It is not on the front burner.

Mr. BROWN. No.

Mr. RITTER. If the central focus—I think the Democrats and Republicans are agreeing on this—if the central focus is industrial competitiveness, as some feel—there is an area of uncertainty—the next energy crisis, the next space race—then you know then you need the private sector input in a way which we don't have today.

I guess, Dr. Lambright, at the end of your testimony you talked about how the Japanese organize and we may need to—we are not Japanese but we need to take a page or two from their book—there is no doubt that their agencies in the realm of industrial competitiveness are laced with private sector interagencies at every single level. In fact, you never know where the private sector ends and the Government begins in the mini-industrial lab activity. So how would we go about doing that?

Dr. TEICH. I think we have got to be innovative. I guess I would disagree in part with my colleague with respect to the role of OSTP, which I feel ought to be in this picture to the extent that a central presidential level agency needs to show its support. What-

ever agency takes over this function needs to have an indication of clout at that level, but I don't think I would give essentially a staff office in the White House operating responsibility for a function of this size and nature. I would simply try to see that the agency, whatever agency it might be, would have clout, would have an indication of support from OSTP and would operate independently.

Mr. RITTER. Do you favor the idea of a Department of Science and Technology?

Dr. TEICH. I am not an enthusiast of the department idea. I think that some of the perhaps less ambitious schemes under the National Technological Foundation proposals and similar ones have some merit that ought to be explored, short of setting——

Mr. RITTER. There is some dichotomy between the basic and applied research and the development of technology and the commercialization and there may well not be—as a matter of fact, if you use the Japanese labs as a model, you will find an incredible spectrum of continuum from the most basic research activity, but its direction and all basic research at some point is chosen for a particular direction some way. You wouldn't want to make that dichotomy, would you?

Dr. TEICH. No; I don't want to separate them, certainly not, but I don't think that under the present structure we are giving enough emphasis to the applied research side of things, and I don't see that the creation of an institution that would—or modification of existing institutions in a way as to provide for better assignment of new missions of this type to be the laboratories would necessarily separate. In fact, I think it could be viewed quite significantly as supplementing existing basic research.

I don't necessarily think, by the way, that the Japanese model, given the differences in their whole financial structure, and the differences between their society at large and ours, really is necessarily the best model for us.

Mr. RITTER. I understand that, but I am just saying there are things that we can learn from the model as we go from our period of uncertainty into our next historical use.

Mr. BROWN. Mr. Ritter, I don't want to interrupt this very important line of thinking; it ought to be pursued further, but in deference to our other witnesses, I wonder if we could just move on a little bit faster. If you have any additional questions, go ahead.

Mr. RITTER. Well, just for the record, I would like to have your comments on how, if we did go in this direction, how would we integrate the very strong private sector involvement?

Dr. TEICH. I would be pleased to submit a statement.

Mr. RITTER. I am sorry, Mr. Brown.

Mr. BROWN. I was at a meeting of the SRT subcommittee yesterday where we didn't finish with the first two witnesses until noon. I thought it was an injustice to the other witnesses.

Mr. Lewis, do you have any questions?

Mr. LEWIS. How do the labs and agencies interface with the international scientific communities? If you have covered this in your text, I apologize for not being here to hear it.

Dr. TEICH. I have not covered it in mine either, and it is an important question. It goes on at various levels, of course. In one sense, the interaction of international scientific communities goes

on as a natural part of the activities of individual scientists and scientific groups, and this is particularly strong in areas of basic research. And some of our national laboratories that perform high energy physics research, for example, which is one of the most internationalized areas of research, one finds resident scientists from other nations at the National Accelerator Lab. People are essentially permanently stationed at each other's laboratories to maintain liaison and it is a very effective form of international communication.

I think that the closer one moves into areas of mission, either economic application or national security application, the more difficult these kinds of international contacts become, and the more they tend to be carried out through more formalized structures of higher levels in the agencies.

Mr. LEWIS. Thank you.

Dr. LAMBRIGHT. I really don't have anything to add to that. That is essentially as I see the interaction. They are mainly through their individual scientists and the more basic, the easier it is for them to have interaction.

Mr. LEWIS. Thank you.

Thank you, Mr. Chairman.

Mr. BROWN. Mr. McKay.

Mr. MCKAY. No questions.

Mr. BROWN. Thank you very much, gentlemen. We appreciate your help.

[Answers to questions asked of Dr. Teich and Dr. Lambright follow:]

American
Association
for the Advancement of
Science

1333 H STREET, NW, WASHINGTON, D.C., 20005 (202)326-6400
CABLE ADDRESS: ADVANCESCI

27 November 1985

The Honorable Don Fuqua
Chairman
Science Policy Task Force
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Fuqua:

Thank you for your letter of 11 October and the kind words about my testimony before the Science Policy Task Force.

I was pleased to have an opportunity to contribute to this important work. As you requested, I have prepared responses to the several questions that accompanied your letter. These reponses are enclosed.

I regret that I was unable to meet the deadline noted in your letter, as I explained to Dr. Watson on the telephone. I hope that this will not inconvenience you or delay the work of the Task Force.

Please do not hesitate to call upon me if I can be of any further assistance.

Sincerely,

Albert H. Teich
Head, Office of Public
Sector Programs

AHT/hs

Enclosure

cc: Dr. Harlan Watson

RECEIVED
DEC 2 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

Questions for the Record

Dr. Teich

1. You say on page 12 that "the reductions in applied research programs may be having impacts on institutions that are affecting their ability to conduct basic research". Could you please explain this statement, and give us some specific examples of how the current administration's reduction of applied research funding is affecting the application of basic research or the conduct of basic research?

2. You point out, on pages 14 and 15 of your prepared testimony, that the Office of Management and Budget and the Office of Science and Technology Policy are the two entities most capable of taking an overview of the basic research program. How can their role in this important function be improved? Or should it be improved?

3. What difference would it make to the performers of research if instead of mission agencies funding the majority of R&D, the science agencies funded the majority; that is, if the National Science Science Foundation were the major funder rather than the "balance wheel"?

4. What are the strengths and weaknesses of having a stronger role for the Department of Defense in the support of basic research relative to the other mission agencies? Is there an optimal balance between civilian and military support for scientific research?

5. Department of Defense and military-related DOE research and development were greater than 50% of all federal R&D in all the years since 1960 except 1978 and 1979. Since FY 1981, federal support for civilian research has decreased 17% in constant dollars, while federal support for defense research has increased 91%. What is the significance of this recent trend?

RESPONSES TO QUESTIONS FOR THE RECORD

Albert H. Teich

1. Reductions in applied research programs may be affecting the ability of institutions to conduct basic research in two ways. First, there is the matter of economies to scale. Basic research efforts and applied research efforts are not neatly segregated within institutions such as universities, nonprofits, or federal laboratories. Often they are conducted within the same laboratories, using the same instruments and support staff, by scientists working side by side. In fact, a single researcher may spend some of his or her time working on projects that officials of the sponsoring agency may classify as applied research and some on projects classified as basic research. Under such circumstances reductions in applied research efforts — if they are not offset by increases in basic research funding — can diminish economies of scale (e.g., spreading the cost of instrument acquisition and maintenance among several projects) and raise the cost of the basic research efforts.

   A second point is that the ties between basic research and application are growing increasingly strong — particularly in such fields as molecular genetics and microelectronics. Thus the issue of what is basic research and what is applied research may be more and more difficult to resolve (and less important in a policy sense). If one cannot really distinguish between basic and applied research, it seems unlikely that one can make reductions in one area without affecting the other.

2. The Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP) are the agencies best situated to take an overview of the federal basic research program. There are a number of ways in which this role can and should be improved. On the OMB side, the most direct way in which the agency takes an overview is in the preparation of "Special Analysis K" of each year's proposed budget. This is a very useful exercise, and its importance as a science policy tool needs to be communicated to OMB's leadership to assure that it continues to be carried out and that sufficient resources are devoted to it. As it stands, however, the analysis is mainly an after-the-fact reporting exercise. Its utility could be substantially enhanced by administrative reforms in OMB giving the unit responsible for the preparation of the Special Analysis some influence over the actual funding levels for basic research in agencies outside its present domain (espcially NIH and DOD).

   On the OSTP side, although the Science Adviser's public statements and policy initiatives give evidence of his deep concern for the health of the nation's basic research efforts, it appears that the office as a whole is too enmeshed in day-to-day problems and staff

work on such major initiatives as SDI to give sufficient attention to the overall basic research budget and to such issues as balance and priorities among disciplines. In view of the fact that OSTP is a White House staff office, it is not easy to see how the Congress might influence the manner in which in which the office's leadership chooses to allocate its efforts.

3. While I would certainly favor a significant increase in the National Science Foundation's budget for basic research, I do not think it would be in the best interest of either the performers of research or the nation for NSF to take over from the mission agencies as the funder of the majority of basic research. One reason, as noted above, is the growing connection between basic research and applications. As these ties grow stronger, the role of mission agency research becomes more important, because mission agency sponsorship can facilitate technology transfer. In addition, the feedback that potential users in mission agencies give researchers may be an important stimulant to the research. Finally, the much-cited pluralism of the current system of support gives research institutions stability based on political and administrative diversity, and multiple points of access to funding sources that a single agency cannot provide.

4. I am not aware of any analytical means of describing an optimal balance between civilian and military support of basic scientific research -- although it seems apparent that neither extreme (i.e., 100 percent military or 100 percent civilian support) would be very good. Between these extremes, the balance is a matter of the relative priority that the nation places on military and civilian matters (which varies with the international and domestic political situation) and the nature of the support systems employed by the various agencies. Some military agencies -- particularly the Office of Naval Research in the early postwar period -- have had a positive reputation in the scientific community for providing a very benign environment for support of basic research. More recently, DOD policy initiatives based on concerns about the flow of scientific information to hostile nations have rasied serious questions about DOD support of basic research. These questions have no clear-cut answers at this point, but the issue of military support of basic research merits careful attention by the Task Force.

5. In order to assess the significance of the recent trends in funding for defense and nondefense R&D one needs to disaggregate the figures within these categories. On the defense side, most of the enormous increase in R&D funding has been on the "D" side of R&D (actually in development, test and evaluation). The growth in defense research has actually been rather modest in comparison. On the nondefense side, large reductions in applied research and development in such areas as energy and environmental research, and the transition of the space shuttle out of R&D and into an operational program, have been partially offset by increases in basic research in NSF, NIH, DOE, and NASA. The result is a rather mixed bag for the nation's R&D efforts. On the whole, this situation is a result of the administration's priorities and interests, rather than specific decisions made on the basis of factors internal to R&D. In my personal view, the administration's extravagance on the military side is largely responsible for the current deficit crisis and the pressures for unprecedented domestic austerity. It represents a serious misjudgement of the nation's best interests. The long-term impacts on science, among many other endeavors, may be very damaging.

October 31, 1985

RECEIVED
NOV [illegible] 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

Honorable Don Fuqua, Chairman
U.S. House of Representatives
Committee on Science and Technology
Suite 2321, Rayburn House Office Building
Washington, DC 20515

Dear Mr. Chairman:

You asked a number of questions to which you wished answers, as a follow-up to my testimony before the Science Policy Task Force on October 2, 1985. What follows are my answers to these questions.

1. Q: What do you see as the future roles for the Federal laboratories?

   A: These laboratories could continue to do what they are now doing. That is to say that they could continue to work on the same missions. They could also broaden their sponsorship and do more work for the private sector and maybe even the states. It is almost certain that they will have to define relationships with universities and industry that will be different from what they have been in the past. This is in line with what I said in my testimony was the new economic development mission. Also, there may be more international collaboration. The labs' educational role may increase. And, there is almost sure to be more technology transfer emphasis.

2. Q: How do smaller laboratories, in agencies such as U.S. Department of Agriculture and Veterans Administration, compare with the giants of NASA and DOE? Have they been through similar funding and mission changes?

   A: We really don't know that much about the small labs. They have not been studied as extensively as have been the larger laboratories. It is a good bet that because they are smaller, they are more vulnerable to swings in funding. They are probably more dependent on their agency sponsors and, therefore, less diversified. They probably have employees from a narrower range of disciplines. At least some of them are perhaps so small that they are submarginal in effectiveness, although this would be hard to document.

Syracuse Research Corporation Merrill Lane Syracuse, New York 13210-4080 Telephone(315) 425-5100

3. Q: If Federal laboratories are given national missions, will these missions supplement or supplant the missions of the agencies which fund the laboratories?

   A: These labs already have national missions in the sense that energy and space are national missions. The question is really one of national missions new to the agency and the country. How do the labs balance the new with the existing missions? Essentially, they must provide good services to agency sponsors. To the extent they have slack resources, they can deploy these resources toward new national missions. Where they are already fully committed, they may have to be provided with additional slots if they are to be redeployed to do something new. The only way to deal with this is by thinking of the labs as a national system. In a national system, those which are underutilized can be deployed to new missions as needs arise. We need an organization above the agencies and the labs to monitor this system as a whole. Only through a monitoring agency can this system be given any kind of guidance. OSTP would be the logical agency to play this monitoring role.

4. Q: Please comment on present and future technical staffing needs at the Federal laboratories in terms of quantity and quality.

   A: From previous studies, like the Packard Report, it can be said that quantity is not really a problem. The number of people presently in the system as a whole is sufficient for most needs. There are surges of needs (e.g., the energy crisis) where a lab may have to staff up quickly.

   Quality is undoubtedly a problem in certain cases. Attention has to be given to matters of incentives, as for example salaries. Also, flexibility in hiring is needed to bring on new professionals, thereby avoiding stagnation. In labs which have personnel ceilings, there could be a great problem of lack of fresh and innovative ideas from new people. There is also a need for stable funding for long term projects in laboratories, as there is in universities and industry.

I hope that these answers are responsive to your needs. If you have further questions, please do not hesitate to ask.

With best wishes.

Sincerely yours,

W. Henry Lambright

W. Henry Lambright

WHL/kk

PANEL 2: SCIENCE IN THE U.S. DEPARTMENT OF DEFENSE

Mr. BROWN. Our next panel consists of Col. Donald I. Carter, U.S. Air Force, Acting Deputy Under Secretary of Defense for Research and Advanced Technology, U.S. Department of Defense, accompanied by Dr. Leo Young, Director, Research and Laboratory Management; and Dr. James A. Tegnelia, Acting Director, Defense Advanced Research Projects Agency.

They will tell us about research policies at DOD. We are happy to have you here, I think you can help us understand some of the fine detail.

[A biographical sketch of Colonel Carter and Dr. Young follow:]

COL. DONALD I. CARTER

Donald I. Carter is the Acting Deputy Under Secretary of Defense for Research and Advanced Technology. He is responsible for policy formulation, program development and program implementation of the Department of Defense Science and Technology program, a $5.5 billion annual effort. It is the largest multi-disciplined federally funded science and technology program in the U.S. involving about 53,000 people and over 70 DOD laboratories. He works primarily with the Congress, military services, universities, industry and counterparts in allied nations.

Colonel Carter was born in Attala County, Mississippi, on July 1, 1936. He attended Mississippi State University, graduating in 1958 with a Bachelor of Science degree in Civil Engineering.

His first Air Force assignment was at Little Rock Air Force Base, Arkansas, as the base bioenvironmental engineer. By 1960, he moved to Vanderberg Air Force Base, California, as a bioenvironmental engineer working with the Atlas, Titan and Minuteman strategic missile systems.

In 1964, Colonel Carter was named staff bioenvironmental engineer for the Aerospace Medical Division, Brooks Air Force Base, Texas. He served as liaison between biotechnology and hardware research and development organizations. He was assigned to Clark Air Base, Philippines in 1969 as a bioenvironmental engineer responsible for the Bioenvironmental Engineering Program for Air Force bases in the Philippines, Thailand and Taiwan.

Returning to the United States in 1971, Colonel Carter was assigned to Headquarters, U.S. Air Force, Washington, D.C. as staff officer and assistant for Medical Research and Standardization. In 1975, he became the Military Assistant to the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology). In July, 1979, Colonel Carter was named Director of Research and Development for the Aerospace Medical Division and assumed his present position in 1984.

He is a graduate of the Squadron Officer School; Air Command and Staff College; and Air War College.

His decorations and awards include the Defense Superior Service Medal, Air Force Legion of Merit, Meritorious Service Medal with one oak leaf cluster, Commendation Medal, Vietnam Service Medal with five bronze service stars and the Republic of Vietnam Gallantry Cross with Palm.

DR. LEO YOUNG

Current position: Director for Research and Laboratory Management, Office of the Under Secretary of Defense for Research and Engineering (November 1981–present).

Previous affiliations: Naval Research Laboratory (1973–1981), Stanford Research Institute (1960–1973); Westinghouse Electric Corporation (1953–1960).

Education: Ph.D. (Electrical Engineering), The Johns Hopkins University, B.A. and M.A. (Mathematics, Physics), Cambridge University, England.

Publications: Authored, co-authored or edited 14 Books, 20 patents, more than 100 papers.

Professional Societies: President, IEEE, 1980; Fellow, IEEE, 1968; Fellow, AAAS, 1979; etc.

Visiting Professor/Lecturer: Stanford University, Stanford, California; Leeds University, England; University of Bologna, Italy; Technion, Israel; Technische Hochschule, Braunschweig, FRG; George Washington University, Washington, D.C.

STATEMENT OF COL. DONALD I. CARTER, U.S. AIR FORCE, ACTING DEPUTY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ADVANCED TECHNOLOGY, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC, ACCOMPANIED BY DR. LEO YOUNG, DIRECTOR, RESEARCH AND LABORATORY MANAGEMENT, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC

Colonel CARTER. Mr. Chairman and members of the task force, I appreciate the opportunity to testify before this task force which has been specially established to hold hearings on science in the mission agencies and Federal laboratories.

Today I will describe our objectives for the DOD science and technology program, the role that it plays in the development and acquisition of material for the DOD, the relationship of S&T to the Soviet threat and the means by which the program is managed and executed in DOD.

Major developments in Soviet military capabilities pose new challenges to us. The Soviet military buildup, both quantitative and qualitative, has produced a major shift in the nuclear and conventional balance. The Soviet military posture has become increasingly more capable in its offensive orientation. The Soviets have significantly extended the global reach of their military forces, enhancing their ability to project influence and power, especially in the Third World.

Since 1981, substantial progress has been made toward ensuring that our military capabilities are strong enough to fulfill their critical purpose. The technology that provided the options for this progress was developed over the past two decades by the DOD S&T program in partnership with the technology community of our private sector.

We plan to continue reliance on the technology edge. It is the most viable of our options. We plan to continue to make full use of the in-house laboratories and the industrial sector. In addition, we will continue to strengthen our relationship with the university community by allocating to them a significant portion of the basic research program, by continuing our program of upgrading university research instrumentation, and by supporting efforts to increase scientific and engineering education in areas of interest to DOD.

The DOD science and technology program request for fiscal year 1986 is $5.3 billion which covers the combined Army, Navy, Air Force and Defense agencies programs. Of this amount, $971 million is for research and $2.6 billion is for exploratory development and $1.7 billion is for advanced technology demonstrations. The S&T program also encompasses the Strategic Defense Initiative and our fiscal year 1986 request for SDI is an additional $3.7 billion.

When Congress established the Office of Naval Research in 1945, DOD became the first Government organization to formally support basic research. Our commitment to research continued with the establishment of the Army Research Office, the Air Force Office of Scientific Research and the Defense Advanced Research Projects Agency.

Today we are but one of several major sponsoring agencies for basic research in the physical sciences and engineering along with NSF, DOE, and NASA.

There was a steady erosion in DOD sponsored research in the decade 1965 to 1975, both in absolute terms and as a percentage of the total Federal Government support for basic research. In constant dollars, DOD support for research in fiscal year 1975 was only one-half of what it had been in the midsixties.

We are attempting to recover to our 1965 level of effort. Similarly, as a percentage of the Federal Government's support for research, the DOD share fell from over 25 percent in the early 1960's to 11 percent in 1975, and has remained at that reduced level.

We employ directly 105,000, 3.6 percent of the Nation's scientists and engineers in our civilian and military work force. In addition, another 13 percent are directly linked to defense budgets and programs. We, therefore, have an important, although by no means dominant, stake in the quality and supply of the national pool of scientists and engineers. Other institutions and sectors of our economy cumulatively have an equal, if not greater, impact and leverage in working these problems.

Over the years, our program has supported the development of such crucial technologies as atomic energy and radar which have had a major impact on the very nature of warfare, the laser, superconducting devices, integrated circuits, intercontinental missiles, aircraft and missiles, command and control systems, and strategic and tactical surveillance.

Our S&T program is executed by teams of scientists and engineers working within the DOD, industries, and universities. Universities are the major performers of research, conducting about one-half of the effort. This is not surprising since universities are the Nation's primary resource for research. They are involved in a much smaller amount of applied research and development.

Our in-house laboratories are the key integrators of the S&T program and play a lead role in research and exploratory development. They help lead the search for new knowledge and concepts. The in-house laboratories provide analytical advice and technical services in planning DOD's R&D program. They provide the strong base of technical knowledge necessary to help make DOD a smart buyer.

Industrial participation in the program gives us access to the highly skilled work force and extensive facilities of our Nation's industries. Involvement of industry in the exploratory development and advanced technology demonstration programs also facilitate the transition of the technology to systems development and production.

The Deputy Under Secretary of Defense for Research and Advanced Technology's responsibilities are to provide the policy and guidance to be followed by the services in their execution of the program and to maintain oversight to ensure the productivity, strength, and vitality of the program. In executing these responsibilities my office serves as the DOD point of contact for the scientific community. Through our role as DOD's S&T focal point, we coordinate the program across the services, resolve technical differ-

ences arising in the separate service programs, and enhance the return on the S&T investments in defense.

The S&T program is planned, formulated, and executed by the three services, DARPA, and DNA. The process of defining what work needs to be done involves consideration and evaluation of the projected operational needs and the technological opportunities for meeting those needs. Many more programs are proposed than can be accommodated within our budget. The S&T programs must compete for funding with the other requirements for systems development, equipment acquisition, operations and maintenance, military construction, et cetera. We widely publicize our program requirements to potential performers.

Coordination is a significant element of planning and executing a research and development program. And we do this through several mechanisms including an extensive documentation center that provides information on planned, ongoing and completed programs for DOD units, defense contractors, and other interested Government agencies; through international agreements with our allies; and, in the domestic arena, through a series of formal and informal activities.

The transfer of the results of the S&T program is accomplished through many routes, depending upon the nature of the program. For basic and applied research, the dominant means is through publications in professional journals and reports. These are also made available through the established information sources such as the Defense Technical Information Center and the National Technical Information Service.

A more effective route to infuse the latest technology into DOD operations is through close collaboration between extramural and in-house laboratory researchers and with systems development.

As we look to the future, we see some areas which will demand our attention to insure technological advantage. Included are the needs for science and engineering education and laboratory modernization both university and in-house.

As I mentioned earlier, the defense industry employs about 17 percent of the scientists and engineers in the Nation. A recent National Science Foundation study projects shortages exceeding 10 percent of the work force by 1987 in disciplines particularly important to DOD: aeronautical engineers, computer specialists, and electrical engineers.

We take an active role in S&E education. Our direct funding of university research to develop new technology also contributes to S&E education. On average, $1 million of $6.1 research funding in a university provides financial support for approximately 10 to 15 graduate students. On that basis, our research program provided financial assistance for well over 4,000 graduate students in 1984.

In 1983, we initiated a new program to provide funding dedicated to the purchase of some of the more expensive S&T equipment items required to modernize university laboratories. The University Research Instrumentation Program is a 5-year, $150 million program to provide items of equipment in the $50,000 to $500,000 price range which can be used in research of primary concern to the services. In our first 3 years, we awarded $90 million in over 650 grants to 152 universities in 47 States. Awards for the next incre-

ment of $60 million for fiscal year 1986 and fiscal year 1987 will be announced next spring as the result of the evaluation of proposals due in by November 1985.

In fiscal year 1986, we will initiate a new DOD-university research initiative. $25 million has been requested in the research program for two major thrusts.

The first thrust includes fellowship, assistantship, exchange scientist and instrumentation programs. We will involve our in-house laboratories and scientific research offices with the objective of enhancing the Nation's science and engineering capability and, at the same time, strengthening the interaction between in-house laboratory and university researchers.

The second thrust of this new initiative will be the initiation of multidisciplinary science and engineering research programs in a number of high risk, potentially high payoff areas such as materials, fluid mechanics, aeronautics, biotechnology, communication networks, computer science, and microelectronics. We have high hopes for this new start.

As a matter of fact, the House-Senate Conference Committee on authorization increased our $25 million request to $100 million total.

Mr. BROWN [presiding]. We still have two committees to go through.

Colonel CARTER. Thank you, Mr. Chairman.

[The prepared statement of Colonel Carter follows:]

HOLD UNTIL RELEASED
BY THE SUBCOMMITTEE

THE DEPARTMENT OF DEFENSE STATEMENT ON SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

By
COLONEL DONALD I. CARTER, USAF
ACTING DEPUTY UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ADVANCED TECHNOLOGY

BEFORE THE TASK FORCE ON
SCIENCE POLICY OF
THE COMMITTEE ON SCIENCE AND TECHNOLOGY OF
THE UNITED STATES HOUSE OF REPRESENTATIVES
99th CONGRESS, FIRST SESSION

2 OCTOBER 1985

Mr. Chairman and Members of the Task Force:

1. INTRODUCTION

I am grateful for the opportunity to testify before this Task Force which has been specially established to hold hearings on "Science in the Mission Agencies and Federal Laboratories."

Today I will describe our objectives for the DoD Science and Technology (S&T) program, the role that it plays in the development and acquisition of materiel for the DoD, the relationship of S&T to the Soviet threat and the means by which the program is managed and executed in DoD.

America's paramount national interests are peace, freedom and prosperity for ourselves and for others around the world. Supporting these interests is our desire for an international order that encourages self determination, democratic institutions, economic development and human rights.

In an increasingly complex world, the fulfillment of U.S. national interests requires military strength because the international order we envision cannot be guaranteed in the face of the numerically superior forces of our adversaries. Major developments in Soviet military capabilities pose new challenges to our defense policy:

- The Soviet military buildup, both quantitative and qualitative, has produced a major shift in the nuclear and conventional balance.

- The Soviet military posture has become increasingly more capable in its offensive orientation.

- The Soviets have significantly extended the global reach of their military forces, enhancing their ability to project influence and power, especially in the third world.

Since 1981, substantial progress has been made toward ensuring that our military capabilities are strong enough to fulfill their critical purpose. Current programs are building more ready conventional forces, more modern nuclear forces, more modern command and control systems, well equipped tactical ground and air forces and greatly improved maritime forces. The technology that provided the options for this progress was developed over the past two decades by the DoD S&T program in partnership with the technology community ot our private sector.

Technology, however, is a perishable commodity. Our task is to sustain progress so that we will have the technical options available to provide future commanders and troops with the tools to accomplish difficult and uncertain tasks in many potential combat environments. However, the lead times from ideas to military hardware are long. Therefore, it is important that we conduct a strong and vigorous S&T program now as an investment in the future well being of the country's security.

The Soviets also recognize the importance of technologically superior weapons and have given their Research, Development, Test and Evaluation (RDT&E) program high funding priority. This heightens the challenge to the United States in that we depend heavily on qualitatively superior weapons to provide an edge over numerically superior adversaries.

In the technology race we do have an advantage not available to the Soviets. In addition to the efforts undertaken in the DoD S&T Program, the U.S. possesses a strong, viable and innovative private sector which is available to do sound research and

development both on its own behalf and in support of the defense sector. The combined efforts of these participants have provided us the lead in most militarily significant technologies but it is important to continue a large and vigorous DoD S&T program to preclude progressive erosion of our position.

We plan to continue reliance on the technology edge. It is the most viable of our options and we must increase our investment to maintain our technological lead. We plan to continue to make full use of the in-house laboratories and the industrial sector. In addition, we will continue to strengthen our relationship with the university community by allocating to them a signiticant portion of the basic research program, by continuing our program of upgrading university research instrumentation and by supporting efforts to increase scientific and engineering education in areas of interest to DoD.

2. THE DOD SCIENCE AND TECHNOLOGY PROGRAM

A. Funding

The S&T program request for FY 1986 is $5.3 billion which covers the combined Army, Navy, Air Force and Defense Agencies programs. Table I is a summary of FY 1985 amounts and our request for FY 1986. Table I includes Research (6.1), Exploratory Development (6.2) and Advanced Technology Development (6.3A).

The S&T program encompasses the Strategic Defense Initiative (SDI). I have outlined the SDI amounts in Table I for information purposes.

There is no doubt that the technological superiority upon which our national security depends is being challenged as never

before. Our only hope of meeting this challenge is through the continued superior achievements in the DoD S&T program by academic, industrial and governmental organizations.

TABLE I
SCIENCE AND TECHNOLOGY PROGRAM
(Dollars in Millions)

	FY 1985	FY 1986
Research	861	971
Exploratory Development	2,281	2,555
Advanced Technology Development	1,377	1,748
TOTAL SCIENCE AND TECHNOLOGY	4,499	5,274
Strategic Defense Initiative	1,389	3,713

Note: Numbers may not add due to rounding

When Congress established the Office of Naval Research in 1945, DoD became the first government organization to formally support basic research. Our commitment to research continued with the establishment of the Army Research Office, the Air Force Office of Scientific Research, and the Defense Advanced Research Projects Agency.

Today we are but one of several major sponsoring agencies for basic research in the physical sciences and engineering along with NSF, DoE, and NASA. The major sponsor of scientific research is the Department of Health and Human Services which emphasizes the areas of medical and biological research. Figure 1 depicts the current distribution.

There was a steady erosion in DoD sponsored research in the decade 1965 to 1975; both in absolute terms and as a percentage of the total Federal government support for basic research. Figure 2 shows that, in constant dollars, DoD support for research in FY 75 was only one half of what it had been in the mid-sixties. Similarly, Figure 3 shows that as a percentage of the Federal government's support for research, the DoD share fell from over 25 pecent in the early-sixties to only 11 percent in 1975, and has remained at that reduced level.

B. Personnel

There are approximately 2.9 million scientists and engineers (S&E's) at work in the nation. We employ 105,000 (3.6%) of them in our civilian and military workforce of 3.1 million people. Of these S&E's approximately 78,000 are civilians -- 72 percent of whom are engineers -- 27,000 are military officers.

DoD also employs almost 740,000 technicians, 22,000 of whom are civilians. About 715,000 technically qualified individuals are in the military enlisted force; they account for 40 percent of total enlisted personnel.

Beyond the 105,000 civilian and military S&E personnel directly employed by the Department, another 13 percent of the nation's total S&E workforce is directly linked to Defense budgets and programs. We, therefore, have an important, although by no

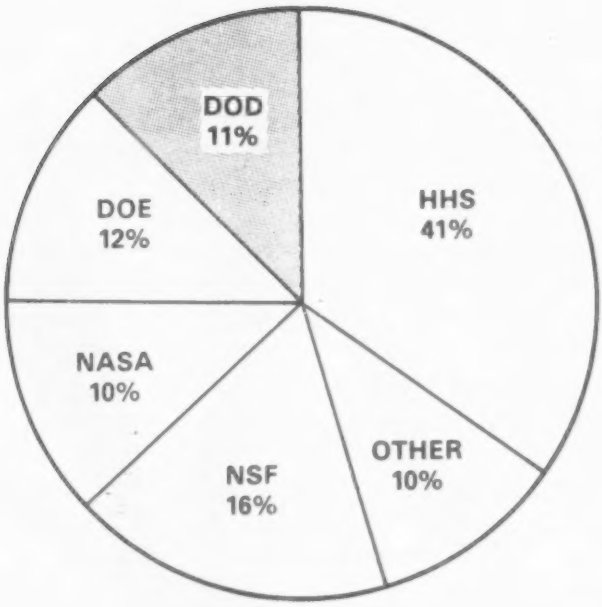


FIGURE 1 - DISTRIBUTION OF BASIC RESEARCH FUNDS BY AGENCY (1985 ESTIMATE)

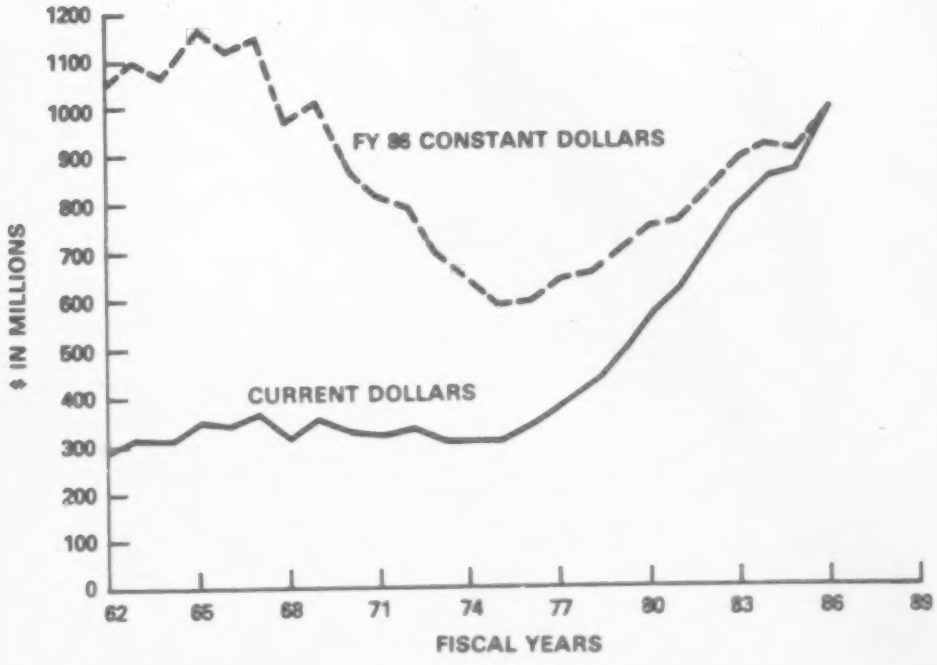


FIGURE 2 - DoD SCIENCE AND TECHNOLOGY TREND CURRENT AND CONSTANT DOLLARS RESEARCH (6.1)

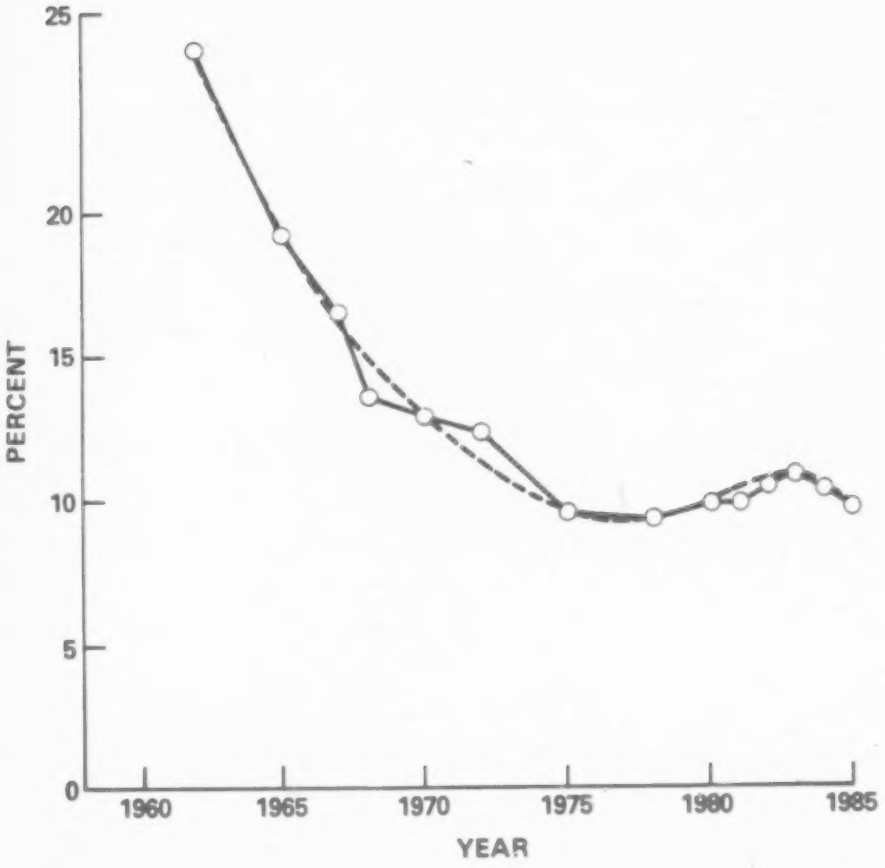


FIGURE 3 - PERCENTAGE OF TOTAL FEDERAL GOVERNMENT SUPPORT FOR RESEARCH PROVIDED BY DoD (6.1)

means dominant, stake in the quality and supply of the national pool of scientists and engineers. Other institutions and sectors of our economy cumulatively have an equal, if not greater, impact and leverage in working these problems.

C. Technical Areas

The DoD Science and Technology program covers a wide range of projects and programs. These projects and programs span the spectrum of military activities and form the basic foundation for our future military forces. Table II gives examples of the technology areas represented in the program.

TABLE II
SCIENCE AND TECHNOLOGY PROGRAM
TECHNOLOGY AREAS

- Space Technology
- Computer Sciences
- Electronics
- Surveillance
- Command and Control
- Communications
- Propulsion
- Aerodynamics
- Night Vision
- Chemical and Biological Defense
- Materials and Structures
- Medical and Life Sciences
- Others

The military Service research offices (ARO, AFOSR and ONR) play a major role in the interface between the operational-capability-driven military needs and the discipline-oriented university research community. Research required to support the DoD mission is concentrated in the twelve classical disciplines shown in Table III.

TABLE III
RESEARCH DISCIPLINES

Physics, Radiation Sciences, Astronomy, Astrophysics	Aeronautical Sciences
	Oceanography
Electronics	
	Terrestrial Science
Chemistry	
	Atmospheric Sciences
Mathematics and Computer Sciences	Biological and Medical Sciences
Mechanics and Energy Conversion	
Materials	Behavioral Sciences

D. Accomplishments

During World War II, our program supported the development of such crucial technologies as atomic energy and radar which have had a major impact on the very nature of warfare. Research during the 1950's and 1960's led to the maser and laser, superconducting devices, integrated circuits, intercontinental missiles, computerized weaponry, vastly improved communication systems, and advances in medical science. Research in the 1970's and early 1980's has made major contributions to aircraft and missile

technology, command and control systems, strategic and tactical surveillance, and has provided the foundation for the Strategic Defense Initiative.

The development of the TRIDENT submarine's advanced echo sounder provides a good illustration of the effectiveness of our S&T program in integrating the effort of universities, in-house laboratories, and industry. A research program initiated in 1963 at Brown University developed the concept of parametric sonar based on non-linear acoustics. Programs at Brown University and the Applied Research Laboratory at the University of Texas turned the concept into hardware. Together with in-house laboratory personnel, Raytheon developed the operational system for the TRIDENT.

The S&T program is woven into the fabric of national life in a pervasive though not always obvious way. The very-high-speed integrated circuit (VHSIC) program now in progress will have a major effect on the electronics industry; VHSIC will eventually enter our lives in ways that will make the wonders of children's talking toys and personal computers seem elementary by comparison. Similarly, work on parallel arrays may profoundly affect the next generation of large computers.

E. Performers

Our S&T program is executed by teams of scientists and engineers working within the DoD, industries, and universities. The funds allocated to the three major performers are shown in Figure 4 for both the research and the total S&T program.

Universities are the major performer of research, conducting about one-half of the effort. This is not surprising since universities are the nation's primary resource for research.

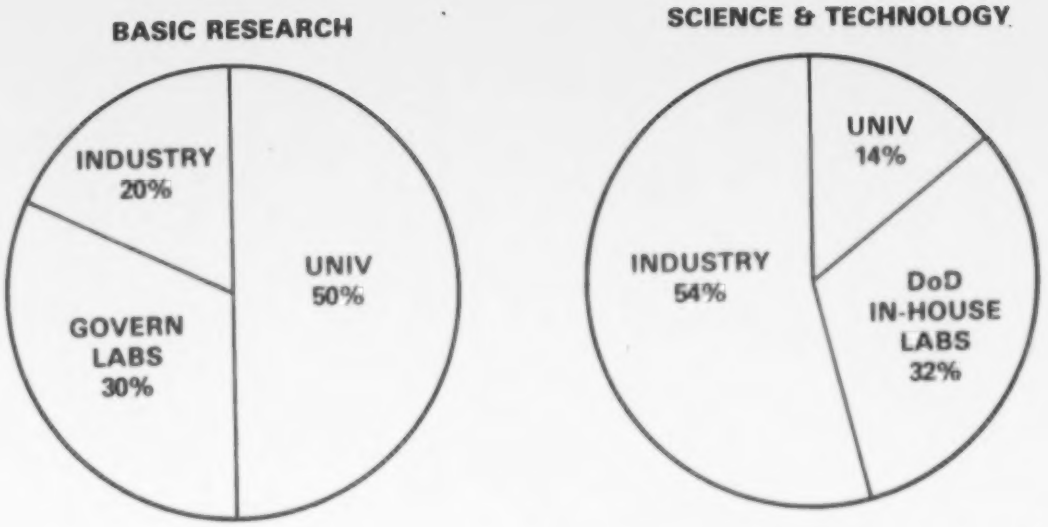


FIGURE 4 - PERFORMERS OF DoD SCIENCE AND TECHNOLOGY

They are involved in a much smaller amount of applied research and development. Their involvement in DoD programs is critical to the achievement of our technology objectives. Close ties with the university community also act to strengthen the in-house and industrial components of the program. A further benefit is that gained through the education of future scientists and engineers in disciplines essential to DoD.

We look to our in-house laboratories to be the key integrators of the S&T program and to take a lead role in research and exploratory development. They help lead the search for new knowledge and concepts. The in-house laboratories provide analytical advice and technical services in planning DoD's R&D program. These laboratories must maintin high scientific and technical competence so that outside technical advice can be evaluated and put into proper perspective in the decision making process. They provide the strong base of technical knowledge necessary for effective assistance in acquiring new systems; that is, to help make DoD a "smart buyer." One of the laboratories' more basic responsibilities is the maintenance of a highly competent technical staff to keep DoD and the Services informed of the latest scientific and technical opportunities pertinent to defense needs.

Industrial participation in the program gives us access to the highly skilled workforce and extensive facilities of our nations' industries. Involvement of industry in the Exploratory Development and Advanced Technology Demonstration programs also facilitate the transition of the technology to systems development and production.

F. Program Management

(1) Management

The Deputy Under Secretary for Research and Advanced Technology is responsible for the DoD Science and Technology Program. My responsibilities are to provide the policy and guidance to be followed by the Services in their execution of the program and to maintain oversight to insure the productivity, strength, and vitality of the program. In executing these responsibilities my office serves as a principal scientific advisor to the Under Secretary of Defense for Research and Engineering, and as the DoD point of contact for the scientific community. Through our role as DoD's S&T focal point, we can coordinate the program across the Services, resolve technical differences arising in the separate Service programs, and enhance the return on the S&T investments in defense.

(2) Program Formulation

With overall guidance from the Office of the Secretary of Defense, the S&T program is formulated by the three Services and DARPA. The process of defining what work needs to be done involves a consideration and evaluation of the operational needs and the technological opportunities for meeting those needs. The needs are derived through a comparison of the future, projected threat with planned U.S. capability and doctrine. Programs are developed to address these needs based on the exploitation of technology opportunities. Addressing long-term, more general requirements and providing the basis for future technology advancement requires the development of new research efforts. Examples of current research efforts include:

signature suppression, less vulnerable communications, space propulsion, improved visibility in degraded environments, elimination of corrosion, advanced energy beaming weapons, artificial intelligence, robotics, and microelectronics. Many more programs are proposed than can be accommodated within the Services' budget. The S&T programs must compete within the Service with the other requirements for systems development, equipment acquisition, operations and maintenance, facilities, etc.

The necessity of supporting a strong S&T program, while addressing other priorities was underscored by the Secretary of Defense in 1984.

> "As we allocate resources to the short term goals, however, we must not sacrifice our national security... We must provide now for the technology that will permit us to acquire, operate and support weapon systems that will be entering our inventory 15-20 years from now. To do otherwise would jeopardize our security in the future since we are relying on the leverage provided by deployed systems which utilize superior technology."

(3) Communication of Requirements

We widely publicize our program requirements. Formal solicitations are included in the Commerce Business Daily. Service research offices issue Broad Agency Announcements. Laboratories and commands provide information briefings to industry. The research community is reached through presentations at professional societies and other national and regional forums.

(4) Program Review

We use a three-tier review process to guide the prioritization of the S&T program, ensure scientific and technical adequacy within the program, and ensure cross-Service coordination.

The S&T investment strategy of each Service is reviewed annually. I chair this review which covers: investment rationale, program technology thrusts, resource allocation (people and funds), and accomplishments. This review provides a top-down examination of S&T programs at the laboratory level.

Science and Technology reviews are structured to provide a middle management review of the Services' S&T programs in specific areas such as Materials and Structures, Environmental Sciences, Computer Software and Systems, etc. These reviews are conducted by my office Directors. At such a review, mid-level managers from each of the Services present the S&T program content in the area with an emphasis on direction at the project level. Major attention is given to quality, program milestones, potential payoffs and technology transition.

In-depth Topical Reviews of the Service's programs in focused areas are conducted as required. These reviews cover the DoD-wide effort in focused areas such as gun and missile propulsion, jet engines, electron devices, chemical defense, etc. The reviews are conducted by staff specialists in my office and feature presentations by laboratory scientists and engineers on the technical programs in the particular area. These reviews provide an in-depth technical assessment of the area and are a valuable coordination tool.

(5) Coordination

Coordination is a significant element of planning and executing a research and development program. We are concerned that we do this well to ensure the maximum exchange of technical information, to preclude unwarranted duplication of effort and to facilitate management and investment decisions. To this end we maintain an extensive documentation center that provides information on planned, on-going and completed programs for DoD units, defense contractors, and other interested government agencies. This is supplemented by other activities.

The nation's defense is based on an alliance concept and it is important that appropriate exchanges be conducted among our Allies. A major portion of Allied coordination is accomplished via bi-lateral and multi-lateral agreements tailored to the needs of participating countries. In the science and technology program area, particularly effective coordination is carried out in The Technical Cooperation Program, the NATO Defense Research Group and the NATO Advisory Group on Aeronautical Research and Development. In our view, the international coordination in areas of defense technical interest are extensive and well done.

In the domestic arena we are engaged in a series of formal and informal activities to achieve coordination goals. Internal to DoD we continuously review the various aspects of the program to optimize our return on investment and to determine programs suitable for joint execution. In the interagency arena formal arrangements exist with other government agencies such as NASA and DoE in areas of mutual interest. Also, there are frequent contacts with the National Science Foundation, the National Academies of Science and Engineering and the university community. And finally, as in the case of all organizations doing

R&D, we are engaged in active sponsorship of and participation in symposia, conferences and meetings in the research and development field.

G. Technology Transfer

The transfer of the results of the S&T program proceeds through many routes, depending upon the nature of the program. For basic and applied research, the dominant means is through publications in professional jounals and reports. These are also made available through the established information sources such as the Defense Technical Information Center and the National Technical Information Service.

A more effective route to infuse the latest technology into DoD operations is through close collaboration between extramural and in-house laboratory researchers and with systems development. Such collaboration provides the immediate benefit to DoD of results and breakthroughs achieved on sponsored programs. In recognition of the importance of this mechanism we are taking steps to strengthen the laboratory-university relationships; partly through the University Research Initiative which will be discussed later.

3. CHALLENGES AND RESPONSES

As we look to the future, we see some areas which will demand our attention to insure technological advancement. Foremost of these are the needs for science and engineering education and laboratory (both university and in-house) modernization.

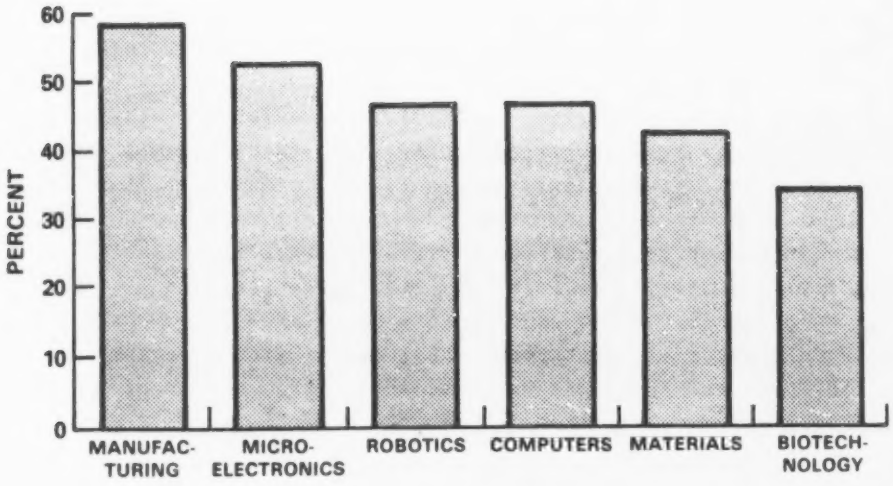
A. Education

The U.S. defense industry is a major employer of the scientists and engineers trained by U.S. universities and colleges. One out of six (17%) scientists and engineers is either directly employed by DoD or works for a defense industry. A recent National Science Foundation (NSF) study projects rapid growth and shortages exceeding 10 percent of the workforce (by 1987) in disciplines particularly important to DoD: aeronautical engineers, computer specialists, and electrical/electronic engineers.

The prospects for attracting greater numbers of outstanding students into careers in science and engineering in DoD are clouded by a number of important factors including:

- Graduate schools, particularly in engineering and related disciplines are having difficulty recruiting and retaining U.S. citizens. The distribution of foreign students in emerging engineering areas is illustrated in Figure 5. Reasons for the decline in the graduate education of U.S. citizens include the lure of industry with existing pay differentials, the increasing cost of graduate school, and the decline in federal financial assistance.

- The number of Ph.D.'s in engineering awarded to U.S. citizens by U.S. universities declined steadily throughout the 1970's and early 1980's, with a net decline of 42 percent between 1968 and 1982. Nearly half of all engineering Ph.D.'s now are awarded to foreign nationals. Foreign engineering Ph.D.'s, even if they remain in the U.S., generally cannot obtain U.S. security clearances and are thus not available for direct DoD employment.



SOURCES. NATIONAL SCIENCE FOUNDATION AND AMERICAN COUNCIL ON EDUCATION

FIGURE 5 - FOREIGN DOCTORAL STUDENTS IN EMERGING ENGINEERING AREAS: 1984

The ability of the United States to maintain superiority in broad areas of science and technology will largely depend on how well universities and colleges are able to recruit and train new scientific and engineering talent. It is especially important that the DoD take an active role in S&E education to insure the future availability of trained personnel.

The direct funding of university research meets our requirements for new technology and contributes to the S&T education program. A 1980 Navy study suggests that, on average, a million dollars of 6.1 university research funding provides financial support for approximately 10-15 graduate students. On that basis, our research program provided financial assistance for well over 4000 graduate students in 1984. In addition, the combination of research contracts and instrumentation programs provides a university research environment that is essential to retain university faculty and to attract graduate students.

During the past decade, DoD has initiated numerous "people-oriented" programs designed to increase the supply of qualified technical personnel, both uniformed and civilian, and to attract exceptional candidates into careers in areas of particular importance to DoD. The complete set of programs is extremely diverse, ranging from secondary school level through undergraduate and graduate school. Some are also designed for postgraduates and university faculty. These formal programs are supplemental to DoD's research programs.

B. University Research Instrumentation

There has been a growing realization among the scientific and university communities, and in state and Federal government agencies and the Congress, that the condition of research instrumentation in U.S. universities declined significantly during the 1970's.

INTENTIONAL BLANK

In 1983 the DoD initiated a new program to provide funding dedicated to the purchase of some of the more expensive S&T equipment items required to modernize university laboratories. The University Research Instrumentation Program is a five-year, $150 million program to provide items of equipment in the $50,000 to $500,000 price range which can be used in research of primary concern to the Services. The program is funded at $30 million per year through FY 87, and approximately equals the annual funding level for equipment items which are routinely included in research contracts with universities. In our first three years, we awarded $90 million in over 650 grants to 152 universities in 47 states. Awards for the next increment of $60 million for FY 86 and FY 87 will be announced next spring as the result of the evaluation of proposals due in by November 1985.

C. DoD-University Research Initiative

In FY 1986, we will initiate a new DoD-University Research Initiative. This program will address some of the widespread concerns about the infrastructure of science and technology in the United States and its relation to a stronger national defense and national economy. Twenty-five million dollars has been included in the Research program, approximately $6 million for each of the three Services and DARPA. We plan to grow this program in the near term. This new start will consist of two major thrusts.

The first thrust includes fellowship, assistantship, exchange scientist and instrumentation programs. The first three, "people" programs, will involve our in-house laboratories and scientific research offices with the objective of enhancing the nation's science and engineering capability and, at the same time, strengthening the interaction between in-house laboratory and university researchers. Additional funding for instrumentation has been included in this initiative.

The second thrust of this new initiative will be the initiation of multidisciplinary science and engineering research programs in a number of high risk, potentially high payoff areas such as materials and structures, fluid mechanics, aeronautics, biotechnology, communication networks, computer science, microelectronics, and optical materials. The intent is to support programs which concentrate talent to achieve the "critical mass" required to accelerate research achievements. These multidisciplinary programs will be managed through a Tri-Service and DARPA committee which will provide close coordination with DoD and a single point of focus for the universities.

We have high hopes for this new start.

4. CONCLUSION

The DoD is supporting a vigorous Science and Technology program which is designed to assure the continued technological superiority of our defense systems. The program is planned to meet our critical needs and exploit technological opportunities. From basic research through development, our program successfully integrates the efforts of the university, industrial and in-house laboratory performers. Through attentive management and careful coordination we are maximizing the return on our S&T investment.

We see areas which require our concern and attention to maintain the momentum of our S&T program. We are addressing the critical areas of science and engineering education and laboratory modernization.

5. BIBLIOGRAPHY

The following studies are representative of the many which have been done in the last ten years on topics related to this presentation:

Technology Base

- The Department of Defense Report on the Technology Base and Support of University Research for the Committees on Armed Services, United States Congress, March 1, 1985
- Report of the Defense Science Board 1981 Summer Study Panel on Technology Base, November 1981
- Report of the Working Group on Basic Research in the Department of Defense Office of Science and Technology Policy, June 22, 1978
- Report of the DoD-University Forum, Calendar Year 1984, December 1984

Personnel/Education

- DoD-University Forum Working Group on Engineering and Science Education, July 1983
- DoD Laboratory Management Task Force, Study of Scientists and Engineers in DoD Laboratories, April 1982

DoD Laboratories

- Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel, Office of Science and Technology Policy, July 1984

- Report of the White House Science Council's Federal Laboratory Review Panel, Office of Science and Technology Policy, May 1983

- USDRE Independent Review of DoD Laboratories, March 22, 1982

- Required In-House Capabilities for Department of Defense Research, Development, Test and Evaluation, October 1, 1980

- Report of the DoD Laboratory Management Task Force, July 1980

Mr. BROWN. All right, did you wish to add anything, Dr. Young?

Dr. YOUNG. No; I think that is a pretty complete summary, perhaps I can help answer questions.

Mr. BROWN. Dr. Tegnelia.

[A biographical sketch of Dr. Tegnelia follows:]

DR. JAMES A. TEGNELIA

Dr. James A. Tegnelia was born on July 8, 1942 in Charleroi, Pennsylvania. He attended public schools in Monessen, Pennsylvania and received his B.S. in Physics from Georgetown University and M.S. in Business Administration from George Washington University. He possesses a Ph. D. in Physics from Catholic University.

Dr. Tegnelia was appointed Principal Deputy/Acting Director DARPA, September 9, 1985. Dr. Tegnelia is currently serving as the Acting Deputy Under Secretary of Defense for Tactical Warfare Programs and the Assistant Under Secretary of Defense for Conventional Initiatives and Director, Conventional Initiatives Program Coordination Directorate located in the Office of the Under Secretary of Defense for Research and Engineering. Dr. Tegnelia manages the tactical weapons program for the Department of Defense. His duties include allocating development resources, overseeing the needs of the military services in new program initiatives, and managing the acquisition of tactical programs. He and his staff of 61 people answer to the Under Secretary of Defense for Research and Engineering on programs totaling over $75 billion. He is also responsible for facilitating integrated program management of several joint Service development and acquistion programs involving the interdiction of enemy follow-on forces. He has represented the Under Secretary on several Joint Chiefs of Staff studies and has been a member of several Defense Science Boards.

Prior to assuming his current duties, Dr. Tegnelia was Director, Tactical Technology Office (TTO) within the Defense Advanced Research Projects Agency (DARPA). He was responsible for a wide range of developments related to tactical warfare and directed the research activities of approximately 22 scientists and engineers. The TTO programs encompassed approximately $221 million of research and development funds and covered the spectrum of technologies in air, land, and ocean warfare. While at DARPA, Dr. Tegnelia held various positions from 1976 to 1983 and as a result of his exceptional performance in these increasingly responsible positions, he was honored with the Presidental Meritorious Executive Rank Award in December 1982.

In previous positions in the Defense Department, Dr. Tegnelia served as Director of the Advanced Concepts Team of the U.S. Army Night Vision Laboratory from 1971 through 1976. During this period, he was responsible for the development of advanced aircraft, tank, missile and individual soldier night vision aids. While serving in this capacity, he initiated development of standardized infrared sensor modules and tank thermal weaponsights. Dr. Tegnelia received the Civilian Meritorioius Service Award for this work.

From 1968 to 1970, Dr. Tegnelia served in the U.S. Army, first with the Project Manager Office for Night Vision and later with the Army Concepts Team in Vietnam. These positions were concerned with test and evaluation management of advanced senosrs and with the suitability of night vision equipment for employment in Southeast Asia. Dr. Tegnelia received the Bronze Star Medal and the Army Commendation Medal for service while in the Army.

He is a member of the Society of Sigma Xi, the Honorary Research Society.

Dr. Tegnelia is married to the former Sandra George of Martin, Tennessee and they have two children, a daughter, Abby and a son, Ryan.

REPRESENTATIVE PROGRAM RESPONSIBILITIES

Current Activities:

All tactical weapons programs in DoD; JSTARS (Targeting Radars); JTACMS (Ballistic Missiles); Tactical Cruise Missiles; Submunition Development; Surveillance Platform Development; RPV's; and Tactical Fusion.

Past Experience:

Assault Breaker; Pave Mover; Tactical "Stealth;" Advanced Cruise Missiles; Forward Swept Wing; RPV's; Focal Plane Arrays; Anti-Armor Submunition; Terminal Guidance; Tank Development; Anti-Tank Missiles; Armor and Warhead Development; Cruise Missile Engines; Night Vision Devices; Fleet Air Defense Development; Torpedo Technology Development; and Acoustic and Non-Acoustic ASW Technology.

STATEMENT OF DR. JAMES A. TEGNELIA, ACTING DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC

Dr. TEGNELIA. Sir, I have prepared a summary statement for you that can be inserted to the record and——

Mr. BROWN. It will be.

Dr. TEGNELIA. For the sake of time, maybe you would like to go to your questions.

Mr. BROWN. I am sorry.

Dr. TEGNELIA. In the sake of time, I won't read that or try to summarize it so you can go to the questions.

Mr. BROWN. You don't want to summarize any of it?

Dr. TEGNELIA. No, sir.

Mr. BROWN. We generally use the time you summarize to think about what you said.

Dr. TEGNELIA. If you would like me to, I will summarize.

Mr. BROWN. Would you summarize in about 4 or 5 minutes, so I can have a chance to——

Dr. TEGNELIA. Sorry to break protocol. Let me take just a few minutes first of all to do two things. The first one is to describe what the Defense Advance Research Projects Agency is, and then the second thing is to tell you a little bit about what some of our research is and give you some kind of feeling for what it is we try to do.

First of all, let me be very clear about the fact that DARPA is not a research laboratory organization. Its total staff is about 160 people of which 90 or so are technical individuals, the remainder of the staff are administrative support and contract support and that type of thing. We have a budget of approximately $700 million a year, which is the responsibility of those 70 or so professionals.

We also are an expert organization which reports directly to the Under Secretary of Research and Engineering and to the Secretary of Defense. We do not report to any of the service organizations or service laboratories. So we are the analog, if you would, of an expert research and development activity.

I mentioned to you the fact that our budget is about $750 million. It is broken up approximately in some of data that I have provided to you, into about two-thirds of what I would consider to be applied research and technology, activities associated with tactical warfare programs, smart weapons, aeronautical research, that type of thing, and also the remaining one-third is associated with what I would consider to be basic science. Now, about $100 million of that $700 million goes to the University community and, to give you just one small piece of information, out of that one hundred million dollars, for every approximately 200,000 dollars' worth of research that we apply to the universities, we expect to have a Ph.D. also graduate as a side benefit. So, we represent about 500 new Ph.D.'s per year coming out of our research.

Let me turn now to some of the thrusts that DARPA is currently working on and use some of those thrusts to give us a little idea about how it is that we operate.

We are currently discussing the opportunity for what we consider to be a space plane, TAV, trans-atmospheric vehicle. The idea is

to build an aircraft which would take off from a runway like Dulles, be able to reach orbital speeds from one single aircraft without use of booster rockets or anything like that, so it would be literally a follow-on to the Concorde or SST or the Shuttle. Now, we believe that the country is getting very close to the kind of technology that it would be necessary to be able to build such a craft and so we are now working with first of all the three services in the Department of Defense and with NASA to be able to define the technology activities which would be necessary to make such a vehicle possible. To give you an example of that, you can imagine that in order to build a vehicle that would withstand escape velocity puts tremendous pressure on things like materials and structures. It will require new propulsion, aerodynamics techniques and also require what I would consider to be fairly difficult control techniques to be able to make sure that you can control the craft in flight. So we use an objective like that, to build an aircraft that could go into orbit, to drive our technology base pursuits so that our techno' gists understand the goals to which their research is oriented.

That is one example. The other example that we have spent a bit of time on is an area called strategic computing. The objective of the Strategic Computing Program is fairly straightforward to elucidate. That is, over the last, say, 25 years, the United States has had its computers increase their processing speed by about four orders of magnitude. It is going to be very difficult to continue that rate of growth. We basically did that over the last 40 years by increasing our capability in integrated circuits and that type of thing. We are going to reach the limit of what we can do with just doing it at the device level. So we are looking at new architectures for computers which will be able to let the data be processed in ways which will be faster than the current one calculation at a time method the way computers operate. That way we think we can continue the growth of the number of operations, that these computers can do—the same growth we have had over the last 20 years—and keep U.S. lead in information processing technology and computer sciences.

By way of summary, that new computer program is one where we have put very large amounts of money into university base, to have the universities continue to give us flexible new ideas in the area of computer sciences, material sciences, and the like, so that the Department of Defense has new innovative historic approaches to next—generation defense equipment. That in summary is the mission of the Defense Advance Research Project Agency.

[The prepared statement of Dr. Tegnelia follows:]

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

STATEMENT

BY

DR. JAMES A. TEGNELIA

ACTING DIRECTOR

BEFORE THE TASK FORCE ON SCIENCE POLICY

OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY

OCTOBER 2, 1985

I. Introduction

Mr. Chairman and Members of the Task Force:

Thank you for the opportunity to present DARPA's perspective of its role as a Mission Agency which supports a significant amount of basic and applied research. The Task Force's objective of clearly defining the issues and options in the Government's role in supporting research is certainly necessary. In today's environment technology dominates national economic and security well-being, but the research underlying this technology has become very expensive and its support is provided in large measure by the Federal Government.

II. DARPA History and Charter

DARPA was created in 1958, in part as a reaction to the launching of Sputnik. Its creation also was a realization of the need for an organization within DoD to formulate and execute research and development (R&D) projects which expand the frontiers of technology beyond the well-identified requirements or missions of the military services and their laboratories. DARPA's programs encompass a wide range of scientific disciplines which address the full spectrum of the anticipated security needs of this nation.

DARPA's function resembles that of corporate research in private industry. Its programs focus on scientific investigations and proof-of-concept demonstrations of revolutionary products for use in future strategic, tactical, rapid-deployment, and sea-power scenarios. The Agency explores the possible military benefits of new and unconventional concepts and technologies for all Services, without specific role or mission limitations.

DARPA's investment strategy is guided by DoD's responsibility to maintain technological leadership in defense capabilities. Although R&D projects in advanced technologies often are high-risk, DARPA's role is to assume these risks (with the clear possibility of failure) when it is convinced that, if the technology succeeds, a breakthrough advancement in military capability results. In a very real sense, DARPA is a venture capital organization which supports high-risk, high-payoff science and technology that requires five to ten years or more to mature, i.e., well beyond the time-scale that private venture capital expects technological success, let alone operation at a profit, to justify upfront investment in research concepts.

III. Impact of DoD and DARPA-Supported Research

Time does not permit justice to this factor; however, several premier items serve as reminders of the impact of DoD's research endeavors on both national security and economic growth. For example, although the invention of the integrated circuit (IC) did not occur under a specific DoD effort, the activity leading up to it was spurred by the DoD search for a "molecular electronics" to reduce size and power and increase reliability of electronic systems. Subsequent to invention of the IC, DoD research played a major role in the early, expensive, high-risk, high-payoff stages

(1960-1965) of IC development. Similarly, nickel-based superalloys developed by DoD made possible today's military and commercial jet engines. Significant research achievements specific to DARPA and of both military and private sector significance include rapid solidification superalloy technology for enhanced jet engine performance, artificial intelligence, packet switching, gallium arsenide integrated circuits, and the creation of the Materials Research Laboratories (now sponsored by NSF as the Interdisciplinary Laboratories Program).

IV. DARPA's Organization and Mode of Operation

Within DoD and, in fact, across the Federal Government's R&D activity, DARPA has several unique attributes. Critical to fulfillment of its mission to pursue high-risk, high-payoff research concepts and new scientific or technical developments of possible military significance is its organization and mode of operation. The Agency has no laboratories or other operations which become deeply involved in advanced development of research concepts of proven (or still seeking) technical feasibility. Hence, maximum flexibility is maintained to pursue radical new approaches to perceived problems/opportunities. Furthermore, DARPA pursues a policy of technological change. Research concepts or projects usually are explored for about three to six years to verify or disprove their viability. Those judged to be infeasible obviously are terminated. Those judged successful are transferred out through: (a) joint Service efforts; (b) pervasive incorporation in Services and/or private sector development efforts (this is particularly true of successful basic or applied research efforts); or (c) by self-imposed termination even if judged by DARPA to be successful. The point is that no scientific or technical concept, successful or not, is pursued indefinitely. This is crucial to the Agency's ability to have resources to respond quickly to unexpected opportunities. An additional aspect of this continual technological change is that, historically, DARPA has had a technical staff turnover with an average residency of several (4-6) years.

As a final note on DARPA's organization and mode of operation, and possible implications for the private sector, it is of interest to note some similarities in the organization of the often discussed Japanese MITI (Ministry of International Trade and Industry). MITI coordinates (and apparently highly successfully) national technical initiatives such as in Very Large-Scale Integrated Circuits (1976-1980). A current example is the "Next Generation Industries Program." Compare this program's goals--"R&D very useful to society and industry, but requires a considerable investment of both time (generally 10 years) and money, and is therefore too risky for private companies to conduct by themselves"--with the high-risk, high-payoff, technical feasibility goals of DARPA. This program, as with other MITI efforts, is of limited duration (ten years in this case) and is pursuing high-risk technological concepts in advanced materials, future electronic devices, and biochemical technology. Also, MITI has no laboratories, although it does create them for specific periods (e.g., five years) in support of specific projects. A current example is the Opto-electronics Laboratory which is developing a host of technical capabilities for communications and information processing.

V. DARPA Support of Research

DARPA R&D funds are comprised of research (6.1), exploratory development (6.2), and advanced development (6.3A) monies. Perhaps the best measure of DARPA support of basic and applied research in the sense of the Task Force definition is the Agency's investment in university research. This was $100.1M in FY 1984, or approximately 11.7% of DARPA's budget of $862M. In turn, about 15% or $15M of this university support was used to purchase instrumentation. A DARPA university funding history is attached as Appendix A. A survey of our university research efforts indicates that for every $100,000 to $200,000 of funding/per year, one PhD is granted (i.e., 500 or more in 1984). Also, 50% to at some universities as high as 75% of the PhD's granted in the engineering, computer, and physical sciences were supported in part at least by DoD.

VI. Selection of Projects and Specific Research Efforts

Assessment of ongoing research programs and evaluation of the potential of candidate new projects is done by the DARPA Director and his technical staff, under overall policy and objective guidance provided by the Secretary of Defense and the Undersecretary of Defense for Research and Engineering. The project evaluation/selection process makes extensive use of technical advice and determination of military relevancy by external groups such as the Defense Sciences Board, JASONS, USDRE's Advisory Group on Electron Devices, and DARPA's Materials Research Council. At the research level it is important to note that candidate projects frequently stem from small individual investigator grants of the Services' Research Offices as well as NSF. The synergism between DARPA's larger, focused, and generally more applied research efforts, and the individual investigator grants of its sister research agencies is a very effective process for innovation and subsequent proof of feasibility of advanced technological concepts. Industrial Independent Research and Development (IR&D) projects play a similar role in stimulating new projects.

Selection of specific research efforts in pursuit of an overall research project is done on a competitive basis wherever possible. In projects where possible approaches are very diffuse and difficult to define, well-publicized announcements such as Commerce Business Daily or Broad Area Research statements are used to encourage proposals with new concepts to address the project goals. When several technical approaches to a project goal can be reasonably well-defined, a more formal work statement is issued in a specific solicitation of proposals. In either case the technical expertise of the DoD (and other government) laboratory and research office staff is sought to evaluate and select those proposals with the most promise.

VII. Issues for Consideration by the Task Force

A number of issues should be considered by the Task Force in assessing the support of research by Government Agencies. I shall conclude with brief discussions of several issues of concern to DARPA.

a. Legislation Promoting Competitive Procurements.

In order to improve efficiency and competition in DoD's procurement of hardware, Congress has passed legislation which expanded substantially the procedures to assure competitive procurement. This legislation also is being applied to contracting for basic and applied research, and has further increased an already lengthy proposal-to-contract cycle. This makes it more difficult for DARPA (and other Agencies) to respond quickly to new opportunities, and discourages dynamic and innovative researchers from pursuing government research support. Clearly the purchase of or contracting for intellectual property (research concepts) is a matter quite different from that for manufactured radar systems or radar ranges. For example, publication of an intent to fund a research proposal to pursue a specific concept, so that others could bid if they have similar capabilities, can lead to the disclosure of proprietary information if an adequate concept description is published. Although the Competition in Contracting Act makes provision for the competitive selection of basic research through general solicitations, there is a need to extend use of this procedure. Perhaps extension to exploratory development (6.2 funds in DoD budgetary terms) contracts up to some size, say $500,000, would alleviate this problem.

b. Control of Unclassified Research.

The free-exchange of ideas and experimental results is essential to the success of basic and applied research effort, particularly within the academic community, and between it and the industrial and government R&E communities. On the other hand, it is well-documented that the Eastern Bloc seeks to capitalize on this free exchange to acquire militarily and industrially significant science and technology.

The balance between proper security and free exchange of scientific concepts is perhaps the most difficult problem faced by the Government and the research community today, and it is receiving widespread attention. Future policy must minimize any damaging effects of increasing communication difficulties within the nation (e.g., in university-industry technology transfer). Also, we must recognize that the leading research in a range of technologies is done in Europe, Japan, and other nations. We also must be careful not to stem the flow of innovative ideas into the country from overseas. This inward flow appears to take place through the academic community and a range of government-supported scientific activities (overseas fellowships, participation in and sponsorship of international conferences, etc.).

c. University-Industry Interactions in Research

This topic currently is enjoying a near euphoric expansion of activity. The challenge to Government science policy is to ensure that university/industry interactions remain at their current healthy state. At DARPA we strongly encourage contractual teaming of industrial and academic research capabilities in those many instances where the arrangement results in a unique research capability neither team member could ever expect to achieve alone. Our experience has been that geographic and communications

barriers to execution of these team research efforts rarely have caused any noticeable barrier to progress.

d. University Instrumentation

Recent assessments of university instrumentation have described the lack of state-of-the-art equipment in research universities. DoD has addressed this problem through the University Research Instrumentation Program (URIP). Nevertheless, the problem is of a magnitude that additional efforts are needed. Individual research grant programs cannot accommodate instrument purchases above $25,000 - $50,000 without devastating their "people support." The URIP has advanced this level to an average instrument individual award of $135,000. However, many individual pieces of today's state-of-the-art research equipment cost $500,000 to $3M, and require annually one-fourth to as much as one-half their initial cost for operation, maintenance, updating, and effective utilization. Basic research programs currently are not structured to encompass such individual initial expenditures and annual operating costs.

e. Foreign Nationals in Graduate Research

Widespread concern has been expressed about the high percentage of foreign nationals in the nation's graduate research programs. A survey in 1982 of DARPA-supported university research efforts suggested that about 30%-40% of the graduate students were foreign. However, nearly all (> 90%) have remained in this country (some with difficulty in obtaining work permits, etc.). The percentage of foreign nationals in these efforts appears to have decreased in the last year or two.

f. "Revolving Door" Legislation

Congress has been considering several versions of legislation designed to prevent DoD personnel from accepting employment at firms with which they have had contractual relations in their government position. Some proposed legislation would make it virtually impossible for such government employees to accept new positions outside the government--i.e., no or very few logical private sector employers would clearly be outside the "conflict of interest" sphere. At research agencies such as DARPA, such proposed legislation would make staff turnover difficult (most who leave go to the private sector), and hence stifle one aspect of creating technological changes in the Agency's programs.

I close with thank you again for the opportunity to present DARPA's views on its role in mission agency support of basic and applied research.

APPENDIX A

DARPA's University Funding History

Fiscal Year	($M) 6.1	6.2	Total
1974	21.9	12.6	34.5
1975	19.4	12.3	31.7
1976	17.1	10.5	27.6
197T	3.5	2.3	5.8
1977	17.2	9.2	26.4
1978	17.9	8.2	26.1
1979	21.0	9.7	30.7
1980	19.8	17.3	37.1
1981	27.3	13.8	41.1
1982	39.4	20.2	59.6
1983	46.4	30.0	76.4
1984	53.9	46.2	100.1
Final Grand Total	304.8	192.3	497.1

Mr. BROWN. That is fine, you did an excellent job.

Let me just discuss momentarily the management problem, Colonel Carter, I get the impression that you go to a rather extensive process to make sure that the work done by the labs under the jurisdiction of the various services is well coordinated and prioritized and responsive to what the management feels are the needs of the Defense Department. What about the situation involving interaction with other parts of the Federal laboratories system, for example, when you have some of these ebbs and flows in need for research both within DOD and within Energy or within NASA, how do you interact with these three laboratories outside of DOD in such a fashion that we may be able to optimize the total utilization of the laboratory system for the national interest?

Colonel CARTER. Well, Mr. Chairman, we do have an extensive cooperation and program formulation process that we use within the Department to put the programs together on basically an annual basis. It's really a system whereby we in the Department or in the OSD evaluate the requirements of the services and the operational commands, the unified and specified commands, and project the kinds of requirements that we think we will have downstream 15 to 20 years from now. Based on several inputs, as I say, from the operational, unified, and specified commands and also based on intelligence assessments of what we think the potential enemy may be doing, we provide that to the services in the form of defense guidance and say we think you guys need to do this kind of work for the next several years in your laboratories. The services then provide a technical program back to us within final constraints that says this is how we would like to address those problems that you have laid out. In addition to that, however, then that basically forms the basis for the budget request that comes to the Hill.

In addition to that, we do have a lot of coordination activities with the other departments. We have joint programs that we pursue technically with the DOE and with NASA. We have formalized meetings at the Under Secretary's level, my boss level, with NASA. We have a coordination exercise that is run under the auspices of OSTP under the Federal Coordinating Committee for Science, Engineering and Technology.

Insofar as the ebb and flow of mission agencies and the requirements for work within the mission agencies, it happens not only among this mission agency but within Defense too, and we use that as the opportunity, quite frankly, to adjust the amounts of resources that we are allocating to specific technical areas. As we assess our needs for the next 15 years or so, there are several technologies we think are very vital to us, materials and some of the technologies that Dr. Teich mentioned, some of them that we really need to get on with. As we increase the size of the defense budget in research and exploratory development, that delta increase will go into those particular areas, and by the same token as we are holding the other laboratories either level or decreasing their size a little bit, we accommodate that. We do basically the same kind of thing with the other agencies through similar coordination mechanisms. We looked at it several years ago, as a matter of fact, when

we were in the recession mode as an opportunity for the Department of Defense to pick up good engineers that were coming available from other agencies and we were fairly successful at recruiting engineers and scientists.

Mr. BROWN. Let me just ask one or two specifics, give one or two specific examples bearing on that.

When the Jet Propulsion Lab faced an obvious decline in need for their functions as far as NASA was concerned and sought other customers, looking at the Defense Department, would they deal directly with another Federal laboratory in the Defense Department or would they go to the level of the management of a particular service, like the Air Force, or would they seek some understandings at the level of the Department of Defense itself in trying to do that? How would that be?

Colonel CARTER. I think that happened in a couple of ways quite frankly. One was that the aeronautics people at the JPL became involved with the Army and at the lab level and also at the NASA headquarters level with our officers in the Pentagon to assist in moving some of—not moving the people—but moving some of the work to the JPL.

Dr. TEGNELIA. Mr. Brown, you may be aware of the fact that JPL is doing some work for the Army with regard to battle management systems. What happened in that particular instance, may be—

Mr. BROWN. Under the SDI?

Dr. TEGNELIA. No; in this particular case it's work for the Army.

Mr. BROWN. I see.

Dr. TEGNELIA. And what happened in that particular instance may be a good example of how that process works. The directors of the laboratory work with the Under Secretary and Assistant Secretary of the Army in order to be able to establish a framework for and agreement with the two organizations. There was a program manager's office that was established to be able to manage that activity. That program management office drew on not only the Jet Propulsion Lab people but also the laboratory people within the Department of Defense laboratories and they created a structure in order to be able to do a project. So it worked from the Under Secretary's office all the way down to the bench scientist to come to agreement on where there was room for mutual coordination, and that coordination has worked well over the last 3 or 4 years in this particular project.

Mr. BROWN. Is it codified in some sort of written agreement, say, between JPL and the DOD?

Dr. TEGNELIA. In this particular case, there is a program management charter which formalizes the particular working relationships and each individual or each party to the agreement understands fairly clearly what his responsibilities are in the process.

Dr. YOUNG. I would like to give two examples, one JPL, another known as NBS. Dr. DeLauer, who I think came in a minute ago, can probably shed much more light on this. I remember he and Dr. Goldberger had conversations, who is president of CalTech, had conversations at that time to move it along. So it was done at various levels, including the Under Secretary level and the president of CalTech.

At NBS, National Bureau of Standards, about three years ago, there was recognition both in DOD and NBS that DOD had measurement problems that can be helped by NBS and as a result of this Dr. DeLauer and Dr. Ambler, who is the director of NBS, came up with an agreement and there are currently two individuals, associates, assigned to my office from NBS who are roving ambassadors from NBS and go around and look at any measuring problems we might have and work out solutions for DOD. It works very well.

Mr. BROWN. Well, NBS has a history of doing this kind of work for other agencies and funding is transferred appropriately to take care of the costs of that sort of thing, and it seemed to be an efficient way to handle problems and manage resources also; and we are trying to determine whether the pattern there is applicable on a general, more general basis.

Let me ask for a couple more examples. We are getting into a policy supposition. Suppose we entered into an arms control agreement that limited further development of nuclear weapons, passed a nuclear test ban treaty or something like that. That would have a large impact on Livermore and Los Alamos, I presume. What would be our reaction? How would we handle that situation in terms of utilization of the laboratories? What mechanisms would exist for doing that?

Dr. TEGNELIA. Sir, you may be aware of the fact that the national laboratories have been working with the Department of Defense not only in the area of nuclear weapons packages but also in the area of conventional weapons activity. We do quite a bit of work with Sandia, for instance, in creating new conventional shape charges. Sandia and Lawrence Livermore have very interesting, let me call it, computer processing for smart conventional weapon systems. We have put quite a bit of effort in with both Lawrence Livermore and with Sandia on next generation armor systems for combat vehicles, making use of very different materials than straight steel armors. So there is quite a bit of precedent for trying to bring the national laboratories into the Department of Defense development process for conventional warfare, and I think that on the whole that process is one that is growing as the technology proceeds and I would expect the scenario of the type that you outlined would undoubtedly accelerate that process.

Mr. BROWN. We are talking here about Department of Energy laboratories which, of course, do a good deal and you are suggesting that there could be modifications in the work load for these laboratories that would move from an area which was no longer as much in need to one which had a higher priority.

Dr. TEGNELIA. Yes, sir. What I am trying to say is the technology that had residence in their organization has applications to conventional battlefield as well as to the nuclear battlefield.

Colonel CARTER. I think you are also aware that they are very extensive players in the Strategic Defense Initiative.

Mr. BROWN. Yes, I understand that.

Looking at the example that I gave, Dr. Tegnelia, of this higher velocity plane, this is a cooperative development also, as I understand it, DOD, NASA, and Commerce.

Dr. TEGNELIA. Yes, sir. We are still in the process of working out the management plan for that, but the intent is to involve those three organizations.

Mr. BROWN. There would be no question but what the management plan would require assignment of tasks to a number of different laboratories, I presume.

Dr. TEGNELIA. Yes, sir.

Mr. BROWN. And that would have to be coordinated at the departmental level, I presume.

Dr. TEGNELIA. Yes, sir. What we would imagine happening in this process is to have a fairly senior level, probably at the Under Secretary level, steering group which is responsible for making sure that the proper organizational talent is brought to bear on the program from each of the three organizations that you mentioned, and also to make sure that proper resources are made available to make sure the program can be fulfilled in a well-managed way. But we are in the process of doing that right now. We don't have all of the details of that worked out, and we will develop it this year.

Mr. BROWN. Mr. McKay, do you have any questions?

Mr. MACKAY. Thank you.

I am interested in knowing how responsibility in basic research is allocated between your two agencies, in laymen's terms. Would you say you are the one that is out more on the cutting edge of basic science?

Dr. TEGNELIA. Yes, sir.

Colonel CARTER. Perhaps some of the people in the services may disagree a tad because, indeed, in supporting jointly lots of programs between the services and DARPA, in addition the services programs are much larger than, collectively larger than the DARPA program. We try and select the best proposals that are submitted from the various performers, whether they be in academia, industry, or the in-house laboratories support.

Mr. BROWN. Now, in the National Science Foundation we spent a good bit of time asking questions about their peer review process—how we are making sure we are getting the best potential for the dollar we are spending? Do you have the equivalent of that in DARPA and in your agency?

Dr. TEGNELIA. Yes, sir. We try to do a peer review of almost all the programs that we have. Let me give you one example which has had quite a bit of history behind it. We have an activity called Materials Research Council, and that council has been in existence now for like 15 years, is currently headed by the director of Brookhaven National Laboratory, and they meet during the summer, plus periodically during the year. They are asked by us to give us advice on which areas of research show potential for major increase in the materials area, and we very oftentimes take the advice that they provide us on which directions that we should proceed. So that is an example of the type of peer review and peer advice process that we use. We do it in almost every major area.

Colonel CARTER. I would like to let Dr. Young address it.

Dr. YOUNG. In the basic research area we do use the peer review system in one form or another. There are slight variations from service to service. Some use outside agencies in the very formal strict sense and others use internal resources for peer review. In

the case of the Army, for example, it has a contract with the National Academy of Sciences to provide peer reviews on every single proposal that comes in. In the case of the Navy, they use more internal resources, using the Navy labs and their own ONR scientists and engineers to do review. In the case of the Air Force, both forms are used at the same time. The peer review system is used in one form or another every time.

Mr. MACKAY. Is it realistic to assume that there is coordination—I am interested primarily in the basic research area—that there is coordination between your efforts and those of NSF and NIH?

Colonel CARTER. Absolutely. We coordinate them not only between the services and our individual scientists work together from the offices of scientific research within these three services with not only DARPA but with the NSF. We have also about twice annual meetings with Dr. Bloch at NSF to talk about mutual problems and largely policy matters.

Dr. YOUNG. Coordination takes place at two levels, at the working level and the top management level. At the top management level as Colonel Carter mentioned, we have the NSF coordinating committee actually started by Bob Cooper at the time when he was director of DARPA and he and the director of NSF are the two co-chairmen, Eric Bloch and Colonel Carter. This meets about twice a year. There are many coordinating activities at the working level in each particular technology: materials, electronics and so on. There are quite frequent meetings, quarterly is quite typical, of DOD and NSF scientific offices to get together and exchange, formally sit down for a day, half a day, and exchange whatever has been happening at their agencies. Also proposals that are received are exchanged within a given discipline between DOD and NSF. So it's active at both the working level and top level as well.

Mr. MACKAY. And your priorities, as I understand your written testimony, are basically to assure that there is research that is being done that would keep us competitive in a national security and military sense.

Dr. TEGNELIA. If I might give you an example of the coordinating process that you were talking about, I mentioned the fact we are working very heavily in trying to continue the U.S. lead in computer sciences and information technology. We just completed a major review of Government work in the computer sciences area in order to make sure that we have had proper coordination, proper consultation and minimum duplication; and the report for that activity was sponsored by Dr. Keyworth's office. It has finally just become available now.

But what I wanted is to specifically spend just a few minutes telling you the people, the organizations that play, to give you the extent of the coordination that occurs. My organization participated, Department of Energy, Department of Commerce, National Science Foundation, NASA, CIA, NSA, and it was chaired by OSTP. So we work at the organizational level on specific topics to make sure that the coordination process, particularly on important national areas, is, in fact, fairly well done.

Mr. MACKAY. Thank you.

Mr. BROWN. Just to followup on that question briefly, and I don't want to belabor it, obviously DOD-supported research has kept the United States in the forefront of international commercial activities in a number of important areas: aircraft, computers—you could probably name several more. And, of course, you get criticized in the Department for diverting funds that might otherwise go to development of civilian technologies—unfairly criticized in many cases. But is there any place in the Department where thought is given, not only to the specific defense impact—of course—in computers and aviation, we are talking about dual use kinds of things—but to the overall question of maintaining our economic superiority as part of our, you might say, defense posture or predominance in world economic activities?

Colonel CARTER. Yes, sir. Recognize that most of the work that we do, the balance of it is indeed being done by universities and industry, and I had one company, fairly major company in the States, come through about 2 months ago and visit with me a while. As a matter of fact, they were interested—they had gotten out of doing business with the Defense Department back 15 years ago, and they were interested in getting back in, perhaps getting some support for some of their research from DOD. Their concern is that the technology that they developed in working under a DOD contract, would they be able to use and exploit that technology in the commercial sector and, gosh, the answer is certainly, absolutely. That is why we do it there, as a matter of fact.

To get back to one of the questions that perhaps was raised a little bit earlier regarding the industrial competitiveness, I think there is another player in this overall business of the economic competitiveness in various and sundry facets of our national economy such as the integrated circuit problem that we are currently having in California, such as the steel industry, automobile industry and so forth. That is, you know, the State universities can play a major role in interfacing with the research aspect of those particular companies who are experiencing those difficulties or who foresee those difficulties, and they did make a contribution to the economic vitality of that particular segment of our economy.

Mr. BROWN. Talking about automated manufacturing, I know the Defense Department has got a major interest in this, but it's an area in which we lag in the international competition, and I think it has a security implication. Frankly, this is at the thrust of, the heart of, of what I am trying to get at here.

Dr. YOUNG. Let me touch on manufacturing technology and manufacturing science.

Addressing manufacturing science in particular, we have two centers: one at Michigan and one at Stanford. That is run, I believe, by the Air Force. On manufacturing science, these are university centers. I am not sure how big the funding is. It is probably on the order of $1 million a year to do more or less basic research in manufacturing technologies such as automation, bringing together the sensors, the computers and all the pieces that come together under manufacturing technology.

On manufacturing technology as such, the Air Force Materials Lab has taken a lead in that and there again they are considering putting together an industry-Air Force board and starting a center

at a university, funding both by maybe 30 companies is what they would like to have and the Air Force. Maybe Jim knows more about that.

Colonel CARTER. DARPA does have major activities in this area.

Dr. TEGNELIA. There are several activities, one of which Dr. Young was referring to, particularly associated with the area of robotics and how one, in fact, tries to automate the manufacturing process. We are now in the process of developing through the organization that was mentioned, I think it's at Stanford, a series with the universities, a series of developments of vision systems, of robotic arms, of movers, which would help create a series of a new generation of robot, quote unquote. And the management model which is used there is to create a science center which brings together people who are working on that problem in a university setting because on some of this, for instance, vision systems and manipulators and the like, some very interesting work is being done at universities.

Ohio State, for example, does a lot of work for us in manipulators and levers. To bring the university communities together and the industrial communities together in the same organization, so the technology is transferred from the university base, some of the prototypes at the universities coming into the industrial center through this Stanford center and, therefore, transferred out to the manufacturing base to be used. It's clear while there are multiple applications for that, there are also significant civil applications for that, and we encourage the technology to have that general purpose application about it.

Mr. BROWN. Of course, our goal is to have all the dirty work in society done by robots and the next war fought by robots.

Colonel CARTER. Absolutely.

Mr. MACKAY. You obviously have worked with and I think have done a good job on coordinating the research leading to a specified aim, and that aim being to be competitive in a military sense. From our standpoint, as people who are trying to work with the policy implications of science and technology, would it not make sense for this country to try to orient its basic research in the nonmilitary side toward a recognition that we are also engaged in an industrial competition and would it not be sensible to start thinking in terms of research leading to industrial growth, industrial development? I understand that when you aggregate the statistics around that point of view that you can't find an awful lot that is going on in the American research establishment—in other words, research not aimed at robotics but maybe research aimed at places where there are going to be jobs in the future to give America a technological edge on the places where the jobs are. I saw statistics which may not be current that indicated in the order of three-tenths of 1 percent of our research was going toward industrial development and if you aggregated the Japanese and perhaps Western Europe research effort it would come out to maybe 15 to 20 percent of their research; and I realize there are some spinout and fallout from what you are doing, but, clearly, you are getting, remember, results by orienting your research toward specified goals and clearly you can make a case for what you are doing even

though in basic research some of it is speculative when you first start out.

Would it not make sense for us to orient our thinking around that kind of competition since clearly we are engaged in that competition as well as military competition?

Dr. TEGNELIA. I would like to give you another example that shows we, in fact, try to calculate that into what we are doing.

As you are probably aware of the fact, almost all of our integrated circuit technology is based on silicon as a basic material for doing that work. We have been interested in looking at another material, gallium arsenide, to do that work. It has certain military advantages. It's radiation hardened so you could work in the Van Allen Belt, for instance, but it also has both the military and commercial interests of being a faster processing material than silicon would be.

Now, we had worked that process in the laboratory for the better part of 10 years, and we came on the idea of an initiative, that it was time to get out of laboratories and into the producibility as spinningoff the problem we worked with. Right now I think there are three contractors who are working this in conjunction with General Abrahamson's Strategic Defense Initiative. There are three contractors who are sharing work with us to get that technology into production.

The way the division of effort was set up was the Government established the funding to produce chips and produce computers based on gallium arsenide if the company would invest in the facilities and in the production lines and the like to establish the capability for when the Government decided it had invested enough they would have a commercial capability already established.

As I mentioned to you, at least three companies are, in fact, sharing with us that way and, of course, they have chosen the positions for their facilities in a manner which would permit them to create jobs in an area where the expertise currently existed. So there was supplemental pay-back of job creation, new market generation and new product lines which were certainly of interest to the Department of Defense but also of interest, what we believe will be of interest to the commercial sector as well.

Colonel CARTER. I agree that it is a good opportunity to do that, and I think if one looks at some of the arrangements of the programs that are in the National Science Foundation, some of that sort of philosophy is coming through in the allocation of resources within NSF.

Mr. YOUNG. In discussions inside DOD we are very conscious of economic impact. Although it is not in our charter, we are aware of it. Much of what we support is dual use. It naturally has spinoffs. I don't want to belabor that point. DOD being in defense is motivated to produce a certain kind of product, weapon systems, but there are spinoffs, and let me be specific. We are very much aware of technology transfer in trying to do something about the Federal Laboratory Consortium.

One example was started by a DOD laboratory with the intention of transferring DOD technology into the civilian sector. Another example has not been mentioned, IR&D, so-called independent research and development, where we support part of it but the

companies decide what they are going to do and they bear in mind what strengthens their competitive position and yet DOD supports it because it's in our interest as well as in the Nation's interest. So we are doing this on many levels. Again, there is no concerted policy, but we believe we are contributing very much to the national competitiveness in the world.

Mr. MACKAY. Thank you.

Mr. BROWN. Thank you very much, gentlemen.

We have a number of other questions we would like to go into. You have just raised a number of them in discussing the technology transfer and laboratory consortium. We will ask you to expand in writing if we can impose on you.

[Answers to questions asked of Colonel Carter and Dr. Tegnelia follow:]

SCIENCE POLICY TASK FORCE

Hearings on Science in the Mission Agencies and Federal Laboratories

October 2, 1985

Followup Questions for Colonel Donald I. Carter

1. **How does DOD decide on the proportion of their to use for research?**

Specific, basic research goals are established each year via the Planning, Programming and Budgeting process. These amounts are modified by the prior year Congressional actions, DOD top line adjustments, inflation rate changes, etc., to arrive at the final budget submission in January of each year. We do not make a specific determination of the proportion of funding to use for basic research.

2. **How much DOD-sponsored research is performed at universities, Government laboratories, and industry and how is this research mix determined?**

Within the DOD research (6.1) program, the funding distribution for FY 1985 was approximately: universities - 50%, in-house laboratories - 30%, industry - 20%. The FY 1985 DOD research program totalled $861 million. This mix of performers is not determined by a rigid rule, rather by a continuing judgment by research managers. Factors entering into this judgment are the quality of proposals from potential performers, the scientific opportunity represented by the work, the availability of unique facilities or instrumentation and the demonstrated competence of the proposers.

3. **How are advisory groups used in DOD mission agencies in the formulation and execution of science policy?**

Advisory groups are an important element in DOD science policy formulation and execution. Within the Department of Defense, the Defense Science Board (DSB) and the DOD-University Forum provide the review, advice and perspective of the national science community. The Defense Science Board undertakes studies at the request of the Secretary of Defense, the Under Secretary of Defense for Research and Engineering or the Joint Chiefs of Staff. Reports are compiled by board members with expert outside assistance. These reports provide detailed findings and recommendations to the Department for consideration in determining its science policy. The DOD-University Forum, established as the result of a DSB recommendation and composed about equally of senior DOD personnel and university officials, has given advice on a wide range of research and education issues related to national defense. Within each Service there are advisory groups which operate along lines similar to the DSB. These groups provide recommendations on programs, policy and laboratory oversight. The Service advisory groups are: the Naval Research Advisory Committee, the Army Science Board, and the Air Force Scientific Advisory Board.

4. How does the DOD provide incentives for joint projects between universities, or between universities and industry?

A recent innovation in DOD's extramural research program has been the establishment of multidisciplinary "cluster" programs focused on complex DOD problem areas. These programs, which provide at least three years or more of stable support, are carried out by groups of researchers at universities. Each group is managed by a senior scientist, who serves essentially as program manager, providing clear direction and coordination. Examples of such programs are the tri-Service Joint Services Electronics Program (JSEP) and the Joint Services Optics Program (JSOP), in which the Army and Air Force participate cooperatively in supporting major projects. Although JSEP is not new, this concept of research management is now being emphasized more strongly. In 1976 only 25 programs were of this nature. Over 130 such programs exist today.

Industry-university collaboration is encouraged by incentives in the Independent Research and Development (IR&D) program. In the review and negotiation of corporate IR&D ceilings, credit is given to companies which have strong university interactions in their IR&D program. Additionally, university involvement with small businesses is encouraged by the Small Business Innovation Research (SBIR) program.

5. In your view, to what extent does defense-supported research yield technology which is applicable to the civilian sector, and vice versa?

Technology developed as a result of DOD research has found application in the civilian sector. In addition to improving our defense posture, DOD technology has increased our industrial competitiveness in today's high-technology world. Radar, synthetic rubber, integrated circuits, advanced optics, lasers, resuscitators and heart pumps head a lengthy list of DOD-sponsored technologies which have benefited the private sector. This process is a two-way street because civilian developed technologies are being exploited to solve problems of the armed forces. A current example is biotechnology where research is being performed by DOD to create new protective gear and treatment methods for naturally occurring infectious diseases, and chemical and biological agents.

6. Since the Department funds R&D mainly by contracts rather than by grants, are research and development contracts subject to the same requirements as major procurements contracts or are they adapted to research funding?

Policies and procedures of special application to research and development (R&D) contracting are given in Part 35 of the Federal Acquisition Regulation (FAR). For basic (6.1) research adaptations have been made: (a) special competitive procedures and (b) short form research contracts. Under FAR Section 6.101 basic research (6.1) awards are considered competitive when they result from (i) a broad agency announcement that is general in nature, identifying areas of research interest, including criteria for selecting proposals and soliciting a response from all capable offerors and (ii) are subject to peer or scientific review. This procedure is used by the Service research offices and is being implemented at some DOD laboratories. The short form research contract (DOD FAR Supplement

Subpart 35.70) is an allowable instrument for contracting with educational institutions and nonprofit organizations. It may be used to contract for research based on a proposal submitted in response to a broad agency announcement. It provides for standardized proposal format, incorporation of uniform contract clauses, and inclusion of the original or modified proposal as part of the contract. These serve to lessen the administrative burden on universities in the contracting process.

7. **How are 6.1 and 6.2 funds distributed among performers?**

The estimated FY 1985 percentage of the 6.1 and 6.2 programs accomplished by in-house laboratories, industry, colleges and universities is shown in the following table:

Percent of 6.1 and 6.2 Program by Performer

Performer	Program	
	6.1	6.2
In-house laboratories	30%	33%
Industry	20%	59%
Colleges and universities	50%	8%

8. **How does DOD determine its share of the total contribution to the science infrastructure? How are education and equipment and facilities coordinated among the various parts of DOD and among the various mission agencies?**

DOD recognizes that support for the science infrastructure is important in maintaining the strength of U.S. science and technology. The DOD supports this infrastructure to meet the defense research needs. The DOD has been increasing its support for advanced instrumentation and fellowship programs which will strengthen the infrastructure and enhance the ability of colleges and universities to conduct quality research and produce well-trained graduates. For example, the DOD University Research Instrumentation Program, started in FY 83, was designed to approximately meet the estimated DOD share of university research instrumentation needs.

Coordination of infrastructure (education, equipment and facilities) programs follows the methods used to coordinate the research program. Interagency coordination is achieved through the Federal Coordinating Council; for Research, Science, Engineering and Technology (FCCSET) and formal arrangements with NASA, DoE, and NSF. Within DOD, the Deputy Under Secretary of Defense for Research and Advanced Technology, through the Director for Research and laboratory Management, provides oversight and coordination for these programs.

9. **How does the DOD control publication of 6.1 research results and 6.2 research results? How much basic and applied research are classified?**

The DOD policy on the publication of the results of sponsored research follows the National Policy for the Transfer of Scientific, Technical and Engineering Information published on September 21, 1985. That states in part: "It is the policy of this Administration that, to the maximum extent possible, the products of fundamental research remain unrestricted. It is also the policy of this administration that, where the national security

requires control, the mechanism for control of information generated during federally-funded fundamental research in science, technology and engineering at colleges, universities and laboratories is classification."

Determination of the classification level appropriate for a project is made prior to the award of a research contract. Controls on the publication of unclassified research results, if required, will be agreed on and will be so stated in the contract.

A survey of project sheets covering DOD sponsored research and development between 1978 and 1983 showed:

- About 0.6% of the Research (6.1) was classified and most (71%) of that was DOD in-house laboratory research with the balance conducted by industry.

- About 2.1% of the Exploratory Development (6.2) was classified. Of that amount, in-house laboratories conducted 61% and industry 28% followed by universities and non-profit organizations at 7% and 4%, respectively. University classified research was conducted at university-affiliated "Research Institutes".

10. **How much of the DOD technology base funding is directly weapons-related and how much is more generic in nature, that is, of interest to the civilian sector as well as the military sector?**

The DOD technology base consists of basic research (6.1) and exploratory development (6.2). The basic research program is predominantly generic in nature but is focused on those technologies and disciplines which are of interest to the DOD. The exploratory development program is more applied and addresses such topics as avionics, chemical defense, advanced weapons, submarines, high energy lasers, etc. Thus the technology developed is of prime interest to the military and is weapons related. However, a large number of the principles and techniques developed under the technology base program can have application to the civilian sector. Most of the work in the technology base is unclassified and results in reports which are given unlimited distribution to encourage technology transfer.

SCIENCE POLICY TASK FORCE

Hearings on Science in the Mission Agencies and Federal Laboratories

October 2, 1985

Followup Questions for Dr. James A. Tegnelia

1. **Your data for DARPA university funding history shown in Appendix A of page 6 of your prepared testimony indicate a significant increase over the past five years. Is this upward trend expected to continue, or have you reached a spending plateau? Do you anticipate a future decline?**

The increase in university funding since FY 1976 - FY 1978 has come about through several factors. First, DARPA has been largely responsible for initiation and funding of research in the computer science activities such as artificial intelligence and systems architecture. These efforts were approaching a steady level in the early 1980's, but have received recent (FY83-FY85) enhancement due to the initiation of the Strategic Computing Program, in which university research has an important role. Since this new program attains full funding level in FY 1986, further significant increases (beyond inflation) in this area are unlikely.

Second, in the period FY 1972-FY 1975 DARPA transferred its pioneering Interdisciplinary Laboratory (IDL) Research Program to NSF (the NSF Program now is called the Materials Research Laboratories--MRL's). DARPA's IDL support went from $17M in FY 1972 to zero in FY 1976. since that time, new individual initiatives in Defense Research Sciences (particularly for materials, microelectronics, biological materials, and more recently electro-optics) have been initiated and now are stabilizing at an annual funding of about $13M - $16M annually.

In the long term (next five to seven fiscal years), DARPA anticipates that existing research projects in these two areas (computer science and defense research sciences) will decrease as projects are completed, and the Agency turns its attention to new technological opportunities. However, fulfilling the Agency's mission always will require support by a strong university research program, the content of which changes over five to ten year periods to match demands of new technical thrusts. Consequently, we anticipate that these existing programs will be replaced by new research thrusts in areas such as those now "seeded" but currently not receiving major emphasis, e.g., fluid dynamics/turbulent flow, exploitation of unique properties of biological materials, nanometer size structures, application of expert systems to materials growth and processing, and exploitation of inexpensive multiprocessor supercomputational capability in modelling and understanding physical phenomena.

2. **You state that research programs are evaluated on the basis of technical advice and determination of military relevance. How do you determine military relevance for basic research programs?**

DARPA's mission is to explore and evaluate radical technical concepts, usually at a function or system level, which may produce dramatic new military capabilities if they could be reduced to practice, and also to minimize the chances of analogous technological surprise by any potential adversary. To answer adequately speculative technological "What if...?" questions which arise in fulfilling this mission, basic scientific insight must be acquired related to such topics as realizable materials properties, future size-volume-weight-power requirements to achieve a certain level of computational capability, etc. DARPA's university research efforts are evaluated and selected to provide the missing scientific data required to answer these "What if...?" questions. Hence, these efforts directly support the Agency's assigned mission and are relevant to evaluating potential future directions of militarily significant technology.

3. **How many new projects versus continuations of projects are undertaken by DARPA each year? How do new projects get funding?**

The percent of new projects in any given year average between ten and twenty percent. The origin of defense future technology thrusts is the DOD Defense Guidance Manual issued annually by the Secretary of Defense. DARPA participates in the formulation of this guidance and responding to its direction. Participation and response evolve from DARPA's direct involvement in broad innovative research fields and general awareness of future DOD needs. New projects to support this direction result from DARPA announcements of fields of interest and from unsolicited research proposals from private industry, universitites and Government laboratories. Funds are planned in selected research fields and submitted in the DARPA budget request to Congress.

4. **To what extent does defense-supported research yield technology which is applicable to the civilian sector and vice versa?**

Defense supported research and civilian sector supported research co-exist in a truly symbiotic relationship in which each yields technology significant to the other sector. Perhaps of greatest significance in today's information, communication, and data processing environment is the invention and subsequent development of the integrated circuit (IC). The heart of the IC, the transistor, was invented at Bell Laboratories in 1947. In the period 1950-1960 DOD funded an extensive research thrust seeking a low power, reliable "molecular electronics" to replace vacuum tube circuits in military systems. This research thrust created an atmosphere which catalyzed the civilian invention of the IC (at Texas Instruments and Fairchild Semiconductor) in 1959. Subsequent development of the IC concept in the period 1960-1967 was greatly enhanced by DOD research funding whose particular goal was airborne solid state phased array radar based on IC's and not possible with vacuum tube technology. Since 1967, the commercial market for IC's has spurred extensive civilian research to advance IC

design, processing methods, and processing equipment. DoD now exploits these advance to develop IC's for its own special needs. Finally, the decade of the 1980's has seen the pressure to realize near-term profits cause the semiconductor industry to focus its resources on near-term (one to three years to production) development efforts. Much of the basic research in semiconductor materials, processes, devices, and IC design is being done at universities under DoD as well as other Federal Agency support. This support has become particularly important since the court ordered breakup of AT&T and its impact on Bell Laboratories has reduced the flow of basic research results from that organization into the civilian sector.

Tabulations of representative research contributions of DOD and the Civilian Sector and their impact on each other follows.

DoD Research	Civilian Impact
Gallium Arsenide Devices (1960's)	Light emitting diodes
Gallium Arsenide IC's (1970's-80's)	Satellite communications High performance computers
Superalloys (1950's-70)	Commercial aircraft engines
Rapidly Solidified Alloys (1975-85)	Improved aircraft engines Automotive components
Night Vision/Infrared Imaging Equipment	Security, safety systems
Conducting Polymers	High power density batteries
Computer Aids for IC Process Design and Specification	Production of IC's
Computer Netting	Timesharing, computer communications networks
Selective High Sensitivity	Implanted microsensors for realtime medical monitoring

Civilian Research	DOD Impact
IC Fabrication Processes and Equipment	Reliable radiation-hard IC's for military electronic systems
Biotechnology	Sensors for chemical and biological defense unique materials for enhancing DOD systems performance
Polymers, Polymer Chemistry, and Polymer Prescursors	Composite materials, bullet proof vests, clothing. Raw materials for high temperature ceramics and semi-conductor fabrication
Superlattice and Heterojunction Semiconductor Concepts	High performance devices and circuits for radar, ECM, EW, computer, and communications systems
Optical Fibers	High data-rate, interference free communications

Mr. BROWN. Our last witness has been very patient, Dr. Richard D. DeLauer, former Under Secretary of Defense for Research and Engineering, and we very much appreciate your allowing us to impose on you, Dr. DeLauer, and we will get you through here promptly.

[A biographical sketch of Dr. DeLauer follows:]

DR. RICHARD D. DELAUER

The Honorable Dr. Richard DeLauer is president of the Orion Group Ltd., incorporated in the State of Virginia on December 1, 1984. The Orion Group Ltd. performs professional services for multiple clients to include analysis of technical proposals, market and technical forecasts, financing planning, evaluation of commercial opportunities for product development and product application for both defense related and non-defense related markets. He also serves as a consultant to the Office of the Secretary of Defense.

Prior to forming The Orion Group Ltd., Dr. DeLauer was appointed by President Ronald Reagan to serve in the United States Department of Defense as the Under Secretary of Defense for Research and Engineering (USDRE). Dr. DeLauer was confirmed by the United States Senate as USDRE on May 6, 1981 and served until his resignation on November 30, 1984.

As the USDRE, Dr. DeLauer was the principal advisor and assistant to the Secretary of Defense for Department of Defense on scientific and technical matters; basic and applied research; development and acquisition of weapons systems; communications, command and control; atomic energy; and intelligence resources. He also served as the focal point for all test and evaluation matters, and was the Defense Acquisition Executive (DAE).

Prior to his appointment as the Under Secretary of Defense for Research and Engineering, Dr. DeLauer was responsible for TRW Inc.'s Systems and Energy activities, which employed more than 20,000 people, and provided a wide variety of products and services for aerospace, electronic, industrial, civil and commercial markets.

Dr. DeLauer joined TRW in 1958 following a 15 year career as a naval aeronautical engineering officer. In 1960 he was made director of the Titan ICBM program. Dr. DeLauer was named vice president and general manager of the Systems Engineering and Integration Division in 1965, and assumed the position of vice president and general manager of TRW Systems Group in 1968. He was elected an executive vice president of TRW Inc. in 1970, and to the Board of Directors in 1972.

He is a member of the National Academy of Engineering and a fellow of both the American Institute of Aeronautics and Astronautics and the American Astronautical Society.

Dr. DeLauer is the co-author of two books, *Nuclear Rocket Propulsion*, and *Fundamentals of Nuclear Flight*, and has served as visiting lecturer at UCLA on nuclear rocketry.

Dr. DeLauer graduated from Stanford University in 1940 with an A.B. in mechanical engineering. He received a B.S. in Aeronautical Engineering in 1949 from the U.S. Naval Postgraduate School, and an aeronautical engineering degree (A.E.) and Ph.D. in Aeronautics and Mathematics from California Institute of Technology in 1950 and 1953.

Dr. DeLauer was born in Oakland, California on September 23, 1918. He and his wife, the former Ann Carmichael, have one son, a granddaughter and a grandson.

STATEMENT OF DR. RICHARD D. DeLAUER, FORMER UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING, AND PRESIDENT, THE ORION GROUP LTD, ARLINGTON, VA

Dr. DELAUER. Thank you, Mr. Chairman.

I will give you some time. I have a short statement which I am going to submit for the record. I don't intend to go into detail. My posture statement from 4 years of submitting that to Congress pretty much summarizes how the Department functions in the basic research.

I thought I would at this time kind of focus on some of the things I was sitting in the back of the room listening to.

This whole question of coordination, I know you were very much interested in. It's a reasonably formalized activity; it's not ad hoc. I was a cochairman along with Hans Mark when in the coordinating committee we covered in detail, generally on a 6-week basis, all the efforts going on so that at least we identified areas that looked like duplication and attempts to be as efficient as possible.

There is also another matter which was very, very important that not much was said about. I was chairman of what is called the Intelligence Research Development Council which has every single research director in the Government that has anything to do with research, that has to do with the intelligence field, and we met on a 6-week basis and we had complete carte blanche from the director of Central Intelligence to be able to look at all the intelligence programs and make firm recommendations to him on programs that we had to do. That permitted, in certain cases, activities being covered by the agencies, for instance, to be funded, to be identified for it to be able to be taken advantage of. That was a very powerful committee and very, very well done and money that we spent in that research and development area was done very well.

These meetings covered the whole spectrum of what we could do at Caltech. I had a personal interest being a Caltech graduate. I wanted to see the alma mater succeed, and so he and I worked on the problem, and then I sat down with the assistant secretaries of the services and said, "Look, what programs can we fit in there?" We were successful in JPL. Then the Army started a program that got the faculty all upset. They had had to change the rules there, but we do that.

Mr. BROWN. You couldn't do anything to get the planetary exploration budget increased.

Dr. DELAUER. That is right. We couldn't quite do that. But we sure gave it a go.

On the question of: Is the Department of Defense research program so focused that the question of the utilization and general economy is really happenstance, more than you would expect and you would hope? There has been a tendency to have that as the case, particularly in the research being done by the companies.

Leo mentioned just briefly, and almost in passing, an activity called independent research and development. That is a large amount of money. It runs anywhere from ½ to 2 percent of the total DOD procurement budget, and they have very strict contracting. I used to have to go before Mr. Adabbo every year. We counted the nickels and pennies and he wanted to be sure we were spending the money.

But going back in history, remember there is a proviso by statute which is called the Mansfield provision, which is handcuffing the companies from being able to in many cases get in the basic research area. When they have to show military relevance, in many cases they will not undertake that type of basic research because they will get it disapproved.

I think this committee ought to really look at this thing since you are the only committee that really looks at the whole question of science and technology in the country; all the rest of them are parochial. The energy committee looks on the energy side. We in Defense, in the oversight by Congress in the defense area, look at

theirs. Senator Proxmire gives Golden Fleece Awards a" the time, and so everybody is worried about that. But this commi ee—I have talked to the chairman of the full committee—this committee has got the opportunity, and now you are having the hearings, to look at this thing from a broader standpoint than just the mission-oriented sort of things. I think most of the departments have really become accustomed to being mission-oriented. In my statement, you know, in the very first paragraph I tell you that our research is driven by military needs, which is absolutely true. But the thing is, is the independent research and development which is carried on by the industry and along with universities is a matter where we have an initiative. I gave the contractors kind of brownie points. They got a little higher grade, they got more reimbursed if they would bring universities in to assist them in the independent research and development. As a matter of fact, when I was at TRW, at UCLA we developed a whole new generation of isotope separation on research, and that was all done at UCLA. The brains were there. What we provided were the laboratories and money, and they went ahead and did that.

I would hope that this group would, indeed, take a look at IR&D and the Mansfield amendment. It's beyond the point where it is. There is no way to separate basic from military needs and civilian needs. At the basic level you never know where you are going to go. Nobody knows that microbiology may end up being an electronic device. It looks like that is where we are going to go pretty soon.

Mr. BROWN. Molecular computers.

Dr. DELAUER. Yes, sir, and the whole question—let's take chemistry. We should be looking at the chemical industry, but the chemical industry is treating mental disorders now. You never know where it is going to go. To put it in a straightjacket I think is an error, and you in the congressional role of oversight ought to go back and take a look at that. I think it would be something that would be well worthwhile.

If I could do anything for this hearing, contribute anything, it is to make you gentlemen just re-examine it, debate it, see whether it's worthwhile, because that is a little bit of a handcuff, and we can't afford that now. Your statistics are absolutely correct. In the case of Western Europe, everything I had to do as armament director, when I went over there to push on them to try to use some of the emerging technology to give them better security, security was important, but jobs were No. 1. Jobs are first, and security is second in Western Europe. We are their security and so we have got to make more out of our research dollar, and one of the ways is to unfetter it a bit. You are still going to have the review process. You are still going to have to fit it in the particular budgets. So there are constraints other than military relevance. That gives you enough.

[The prepared statement of Dr. DeLauer follows:]

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

Statement by R. D. DeLauer for
the Task Force on Science Policy

Mr. Chairman, thank you for inviting me to present some of my views on the government/science relationship, and the direction which this relationship should take in the future. I would hope that by carrying out this task, you will develop recommendations that will help the Congress understand the high leverage which mission-oriented basic and applied research can provide to both our national security and domestic economic growth.

During that period that I served as Under Secretary of Defense for Research and Engineering, my annual RDTE posture statement to Congress gave a comprehensive picture of the role of the Service laboratories in carrying out basic and applied research, so I will not repeat those views here. Instead, I would like to present my perspective on the role of basic and applied research in support of national security, and I will try to show how this effort can be transferred to the non-defense arena with positive results.

In general, the military threat "drives" the need for the Defense Department to sponsor both basic and applied research. To give a specific example, let me quickly review the history of the successful Very High Speed Integrated Circuit (VHSIC) program. In the mid-seventies the evolving Soviet threat in submarine and electronic warfare, and their initiatives in increased mobility led the Department of Defense to realize that a significant increase in research and development of high speed signal processing had to be undertaken. It was also clear that their current microelectronics would not be adequate to do the job. Up to that time, microelectronic basic and applied research programs had been paced by commercial needs, primarily those of the computer industry. During that period, computer requirements did not include very high speed circuits. Accordingly, Bill Perry, my predecessor as the Under Secretary of Defense for Research and Engineering, initiated a program whose objective was to develop a family of microelectronics chips that would result in orders of magnitude improvements to Anti-Submarine Sonar, synthetic apeture radar and secure voice equipment. The VHSIC program has been in existance for almost a decade, and has been an outstanding success. Without DoD initiative, the need for these chips would not have developed - the commercial market still does not have a requirement for processing equipment with VHSIC capabilities.

The unique feature of the VHSIC program was the concept of an industrial/university team, and making the resultant technology available to the civil computer industry, as well as the military. This concept is currently being employed in the Defense Research Project Agency's (DARPA) strategic computing program.

In closing these brief remarks, let me give you some examples of research programs initiated by the Department of Defense that proved to be beneficial to the non-defense sector. They have included:

Time Share - Developed by DARPA in the early 60's Time Share became a significant commercial success in the mid-70's.

Packet Switching - Developed by DARPA in the late 60's, now just being introduced by commercial telecommunicators.

Fifth Generation Computer - Results of DARPA sponsored research at Stanford, MIT and Carnegie-Mellon. Appropriated by Japan for world-wide exportation.

As disclaimed in my introduction, this statement was not intended to be definitive or all inclusive, it was intended to give the task force some feel that mission oriented departments like the Department of Defense need to sponsor basic and applied research when the military needs dictate and that these programs have had a positive benefit to the non-defense sector.

DISCUSSION

Mr. BROWN. Thank you very much, Dr. DeLauer.

That is precisely the sort of thing we want to look at. The function of this group is really to look broadly at the policy issues with regard to all of science and technology. I think this specific suggestion you made with regard to the Mansfield amendment and independent research are excellent examples of that.

Along the same lines, I have heard frequently with regard to the Federal laboratories if we do do a better job of utilizing the creative energy of laboratories, if we provide more leeway to the laboratory directors in terms of the expenditure of their budget, perhaps give them a little independent research of a reasonable amount, I don't know what it would be, maybe 1 or 2 or 5 percent or something like that, but it would allow them to focus on targets of opportunity more than they have been able to at the present time. Would you concur in that?

Dr. DELAUER. I think that is a device, one of the devices for it. You will find the complaints out of, at least let me talk about DOD plans, which I know quite a bit about, and we tried some different management approaches, for instance, with the naval labs. We said, "Look, we are going to let you have a level of funding, and you can use that level of funding kind of in an industrial way. In other words, you pick the projects you do and if you want to hire some bright young guys to do that, you go ahead. We are not going to put a manpower ceiling on you and we are not going to hold you to certain kind of rules and in regard to your internal managements." And it has proved very effective as far as the Navy. They went to try to do the same thing in the Air Force and ran into a completely different culture, because generally the services are the opposite that way.

In this case there was a difference, there was a detailed report written by a task force that we had put together at about 1982 on the management of the labs and their people and what it looked like, and they covered both of those subjects. I think it would be good as background information for your hearings. But a certain amount of initiative at the source of the research is absolutely essential if you are going to get the best people to do the best thing, and so I would urge you to take a look at that and if you think that there is too much constraint because of when you put it to OMB and the Office of Personnel Management, congressional committees, pretty soon you find they have constrained the opportunity for research.

We are good. We have got great research. I am telling you all you have to know is how the Soviets are targeting our research. You know that we have got great research. You know that our problem is in something you ought to look at which is the education of the United States in the higher degrees and is something that ought to be done. I had a specific suggestion when I was in the department, never got far, which was to broaden programs like ROTC, for instance, to where you could you would include and pay for the education of bright youngsters who would not necessarily put the uniform on but would give national service, either come into a laboratory for 4-or 5-year terms or stay assistant professors

where we are short of, as an obligation to pay off their college degree, much better than lending them the money and they don't pay it back anyway, if you could recreate an ability to have a broader thing than just the students that end up putting on the uniform.

Mr. BROWN. Would you make that in concrete form, Dr. DeLauer, so that we can look at it.

Dr. DELAUER. Sure.

Mr. BROWN. That is a problem that runs——

Dr. DELAUER. It can be Senate service, any place. It wouldn't have to be DOD, National Science; teaching is one of the things I think at the assistant professor level is probably our deepest shortage. Because of being U.S. nationals and passing security clearances, the industry has snapped them up and as a consequence 50 percent of more of the Ph.D. candidates at major universities are foreign nationals. We are educating the competition. We really are.

Mr. BROWN. We hope it is just the friendly competition.

Dr. DELAUER. Well, it is. It is never not friendly in the marketplace. It may be a friendly net, that is, but a lot of them are going to Toyota.

Mr. MACKAY. I think that is a very important point, and a variation on that same theme is the whole question of university instrumentation and capital outlay needs. We are sort of backing into a situation where we are creating an international competition and given in our Federal system historically we have left the responsibility for the raising of the money and the education of the young people at the State level and they clearly are not able to carry that responsibility.

Do you see—I know DOD is trying to help with the instrumentation problem, and I think they are to be applauded for that—do you see a policy need for the Congress to really rethink the questions on the responsibility for instrumentation?

Dr. DELAUER. Absolutely.

Mr. MACKAY. That is going to end up being the Achilles' heel in the whole operation.

Dr. DELAUER. I will give you a concrete example. I was in fundraising for Stanford as a undergraduate and during the period I was talking to the people in the medical school and they had a biochemist they wanted to hire from the University of Chicago. He came with a $500,000 price tag for instrumentation for his laboratory. Good professors are more expensive than hot shot football players to recruit and if they will come to your school it is important. That is the marketplace, and the University of Texas is doing a terrific job of using their resources to create a center of excellence. In the past they haven't had, and the price of centers of excellence are going up almost exponentially. It is not linear. And so anything that the Federal Government does in doing their mission, I don't think you ought to create anything so artificial that it becomes a political issue in the mission. If you could urge the people doing their mission to be sure that these are the kind of check list we need to have—better instrumentation programs, the whole question of better education base, opportunities for people to serve and yet not have to put on the uniform—things like that, it would contribute to the scientific substance of our country.

Mr. MACKAY. I was even thinking in terms of if you assumed that the raw material of the next generation of industrial competition is the human mind, then you could say from that that we ought to rethink what we are doing in public works. I mean Congress should, in effect, have a policy that had the Federal Government assuming responsibility for capital needs in higher education.

Dr. DELAUER. We have got good examples of works. I can remember early on in the space program, when Senator Kerr was the driving force in the Senate, and when President Johnson, I guess was president, why, I was at TRW then. The response was: "You guys on the West Coast captured the aircraft business because of your universities and your research centers. You are not going to capture the space business. We are going to make the Southern Crescent something else."

Mr. BROWN. Don't you think we have overdone it by putting all those space facilities in Texas and Florida?

Dr. DELAUER. I am a Californian, so are you. I tried to get it in San Bernadino when you and I were out there together. We never quite made it.

Mr. BROWN. Dr. DeLauer, we appreciate your being here. We know you have an urgent appointment, and we want to thank you again for taking the time.

Dr. DELAUER. Mr. Chairman, as you know, this is a favorite subject of mine.

Mr. BROWN. I know it is.

Dr. DELAUER. Anything you can do to help, I appreciate it. I wish you had more time and I had more time. Thank you for the invitation.

[Whereupon, at 12 noon, the Science Policy Task Force adjourned, to reconvene on Friday, October 4, at 9:30 a.m.]

[Answers to questions asked of Dr. DeLauer follow:]

ANSWERS TO QUESTIONS FOR THE RECORD

Dr. Richard DeLauer

1. Is it possible to determine an optimum balance between civilian and military support for scientific research? How might this best be determined?

ANSWER

I do not believe it is possible to determine an optimum balance between civilian and military research. One of the problems is the lack of a credible data base on just how much is being spent at any given time in each area of research. Another problem has to do with the definition of civilian and military research. Since in general civilian research is driven by market forces, while military is driven by the requirement to meet a changing threat, it would be better to try to examine the issue on the basis of industrial and/or academic research.

2. How can DOD make the best use of diverse research performers such as universities, in-house laboratories, industry and not-for-profit organizations?

ANSWER

Since DOD does a reasonable job of utilizing all of the above institutions, it should focus on improving the "process". Since most of industry initiates their research as part of their IR&D programs (which has reasonable oversight performed by DOD) while USDRE I instituted a program that encouraged defense related industries to involve universities in the companies IR&D activities. This program has been marginally successful. Another means of utilizing these institutions is to ensure that university research (6.1 and 6.2) be for the most part unclassified. This is now the case. After a fierce internal battle in DOD, and with the support of the White House Science Advisor, the President did sign such a directive a couple of months ago.

3. What is DOD's current policy on the classification of 6.1 and 6.2 research? How is this policy being implemented, and what impact does it have on the research performers, particularly at universities?

ANSWER

By classification I am assuming you mean security classification. 6.1 and 6.2 have elements that are both classified (up to the highest levels), as well as unclassified. The issue with universities has been over the question of when research becomes classified, and the requirement for prior review before publication. With the promulgation of the Presidential

directive mentioned in the answer to question 2, these issues have been diffused to a great extent. University research funded in the 6.1 and 6.2 categories will be determined to be either unclassified or given a classification prior to funding. If unclassified, there are no restrictions placed on the university, on who can work on it, or what can be published. If an area is classified, the university has the choice of accepting the funding and complying with the rules, or refusing to do the work. A free choice in effect. Reactions from many of the universities that, by policy, will not accept classified projects seems to be that this new policy is workable. I would like to point out that many universities will, and are eager to conduct classified research.

4. In your testimony, you stated that the Mansfield Amendment "fettered" DOD's support of basic research, and hindered DOD's ability to allocate its research funding for a greater impact on the national objective of increasing international competitiveness. Could you please expand on the impacts of the Mansfield Amendment, and DOD's contribution to industrial competitiveness?

ANSWER

The Mansfield Amendment requires that any DOD funded research, either as reimbursed IR&D or contracted effort, must be shown to have a "military relevance" prior to approval of the research effort. This is nonsense. At the 6.1 and 6.2 level it is in most instances impossible to make a distinction. In the large, all effort has some relevance to national security, (i.e., economic strength). Taken in the small, who can, with any confidence, be explicit in what the specific applications of the research might result in, or, which application will be militarily relevant? The Mansfield restriction is just a club in the hands of the many "nay sayers" that are against DOD sponsored research.

The list of DOD sponsored research to industrial competitiveness is extensive, so let me give you a few examples. Most of these efforts were originally sponsored by DARPA.

Computer Technology
Time-sharing
Fifth Generation Computers (appropriated by Japanese)
Pocket Switching
VHSIC
Jet Engine Development

5. During your testimony, you suggested a form of national service to fund the graduate education of scientists and engineers who would then be obligated to teach at a college or university, or perform research at a federal laboratory for a certain period of time. Could you please expand on this innovative solution to shortages of scientists

and engineers?

ANSWER

Since for the foreseeable future, the DOD is dependent on an all volunteer force concept, the services must obtain most of their officer candidates from a DOD funded ROTC program requiring some post graduation active service. As now defined these ROTC students agree to put on a uniform and must be physically able to meet the requirements of the service they volunteer for. These requirements restrict the number of potential students that could use grant financial (not debt) aid.

My concept, which I continue to whole heartedly support, is to expand these programs considerably. Instead of restricting the financial support to only those who are physically fit and who will agree to active military service, I would open the categories of completing obligated service, and limit the physical restriction to the category of how the obligated service is to be discharged. For instance, a promising student who does not want to or is physically able to, could discharge his obligation by taking a civilian job in one of the in-house laboratories in a junior civil service assignment. The length of this obligated service would be the same as if they went on active duty.

Another way that this obligated service could be discharged would be if the individual were willing to go into teaching, either at the assistant professor level, or as a secondary school teacher. Again, the obligation period would be the same.

In my view this program would provide a much larger pool of potential scientists and engineers. In addition, it would have an explicit benefit of giving DOD a larger group of young engineers and scientists that at the present time DOD can't recruit successfully. Also, which is probably the most important result, it would provide a pool of properly educated people that would devote a reasonable period to teaching. One of the reasons the U.S. is not graduating more U.S. citizens as PhD's from the center of excellent institutions is the lack of assistant professors and the costs of going to graduate school. Promising four year students opt to go into industry at high pay, then continue on with graduate work at low or no pay. A program of this sort could help alleviate this situation. The cost is modest when compared with alternatives.

To recap: the value given for value received is by paying for undergraduate education, a period of obligated service is required; With the manner of discharging this DOD obligation broadened to other than uniformed service. In addition, the concept of teaching also serves DOD's needs by creating the where with all to prepare and train a greater number of scientists and engineers.

I recommend the committee review the 1982 report written by Dr. Robert Seamans (MIT) and Dr. Lawrence Korb (DOD) and presented to the DOD/University Forum. This report covers the DOD's needs for scientists and engineers, and can be obtained from Dr. Leo Young in the office of Deputy Undersecretary of Defense for Research and Advanced Technology in the DOD.

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

THURSDAY, OCTOBER 3, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SCIENCE POLICY TASK FORCE,
Washington, DC.

The task force met, pursuant to recess, at 9:40 a.m., in room 2318, Rayburn House Office Building, Hon. Norman Mineta (acting chairman of the task force) presiding.

Mr. MINETA. This is the second day of 6 days of hearings on the topic Science in the Mission Agencies and Federal Laboratories. Yesterday, we heard an overview of science in the mission agencies and Federal laboratories, and science in the Department of Defense. Today, we will be exploring further the role of the laboratories and science in the Department of Agriculture.

Our first witness is Dr. Michael Crow, assistant director for policy analysis at Ames Laboratory and assistant professor of political science at Iowa State University. He will be addressing the general question of how R&D laboratories have evolved over the past 40 years and what these changes mean for R&D policy.

[A biographical sketch of Dr. Crow follows:]

DR. MICHAEL M. CROW

Michael M. Crow currently serves on the Political Science faculty of Iowa State University and as the Assistant Director for Policy Analysis at the Ames Laboratory, a government owned/contractor operated facility of the U.S. Department of Energy.

A graduate of Iowa State University, Professor Crow received his Ph.D. in science policy from the Maxwell School at Syracuse University. His research focus is in the areas of R&D policy, R&D laboratory management and energy policy. Dr. Crow has previously served as the Director of the National Comparative R&D Laboratory Project at the Syracuse University, as the Assistant Director of the Coal Extraction and Utilization Research Center at Southern Illinois University, and as the Associate Director of the Institute for Mining and Minerals Research at the University of Kentucky. He is the author or co-author of a number of publications and also edited the manuscript *High Sulfur Coal Exports: An International Analysis* (1983) and served as co-editor for the manuscript *Strategic Management of Industrial Research* (1984).

STATEMENT OF DR. MICHAEL M. CROW, ASSISTANT DIRECTOR FOR POLICY ANALYSIS, AMES LABORATORY, IOWA STATE UNIVERSITY, AMES, IA

Dr. CROW. Mr. Chairman, my name is Michael Crow and I currently serve as the assistant director for policy analysis at the Ames Laboratory and teach science and technology policy at Iowa

State University. This morning, my goal is to address the general question of how R&D laboratories have evolved since 1945, as well as the more specific question of what these changes mean for R&D policy. The data I will be presenting was collected under the auspices of the National Comparative R&D Laboratory Project which I directed between October 1983 and February 1985.

The fact that R&D laboratories have evolved and changed since the expansion of Government R&D policy in the 1940's is taken as a given. We have all observed the changes from the largely pure-type industrial, governmental, and university laboratories of the pre-World War II era to the large number of R&D laboratory types operating today. Unfortunately, we have not updated our conceptualizations of these organizations with these changes. It is toward this end that our comments today are directed.

This persistence in sticking with our pre-1940 notion of the institutional framework for R&D organizations—industrial, Government, and university—not only ignores the evidence of drastic organizational change, it also fails to recognize the very dynamic nature of this particular organizational form. In less than 100 years, research organizations have evolved from the small product-oriented industrial technical shops of the 19th century to one of the most diverse organizational populations currently in operation. R&D organizations have changed rapidly as a result of the very dynamic environment in which they operate. With over 11,000 R&D organizations operating in the United States, it has simply become impossible to consider them from the once acceptable industrial/university/governmental framework.

By rethinking the institutional framework of R&D organizations, we may better understand the types of institutions performing the task of knowledge production and also improve our concepts as to how technology changes. Current theories assume that industrial, governmental, and university research organizations each have a particular role and function. These assumptions have become so pervasive that they have kept us from fully understanding the extent to which R&D organizations have evolved. In fact, the R&D organization, pursuing the development of new products and processes guided by market forces, has become a rarity. As a result, we have developed over time the misconception that industrial R&D labs are similar and that, while some are heavily influenced by the Government, they predominantly remain guided by market forces. Such an assumption undermines several of the basic precepts of modern organization theory which tell us that organizations behave as a function of their environment. Given this fact, we feel it is foolish to believe that an industrial R&D organization influenced heavily by both the Government and the market is, in fact, the same type of organization as one operating with influence only from the market.

Given the extensive changes in the level of Government influence affecting industrially owned R&D labs, the changing role of market influences of Government labs, and the wide array of hybrid laboratory forms, we feel that the time has come to reconsider the conceptualization of the R&D organization framework. To address this problem we designed and carried out, under the auspices of the National Comparative R&D Laboratory Project, an ex-

tensive analysis of how R&D laboratories have changed over the last four decades. To capture these differences, a new institutional conceptualization for R&D organizations was designed and tested; the remainder of this paper reviews this effort.

To address the problem of evolution among R&D organizations, a new framework for classifying and conceptualizing these organizations, in this case R&D laboratories, was designed. To capture the nature of the effect of changes in the level of governmental influences, while at the same time considering the effect of market influence on an R&D laboratory's behavior, a two-dimensional configuration was designed which would classify R&D organizations according to their dominant external inputs. Regardless of who owned a laboratory, we felt it was important to first classify R&D laboratories according to the extent to which they were influenced by the Government. Was a laboratory public in the sense that it was heavily influenced by the Government, or was it independent of Government influence? Beyond Government influence, we felt that the extent to which the products of an R&D laboratory were influenced by the economic market would also be useful in capturing laboratory variation.

With our goal being the design of an institutional framework that would capture the changes that had or might occur among research organizations, the nine-celled classification matrix shown in table 1 was developed. We established a theory-based classification scheme for R&D organizations which separates research organizations based on the assumption that an organization is a function of its environment. If we assume that the two dominant environments affecting research organizations are the Government and the market, we separated organizations based on the level of governmental influence affecting that organization by a number of proxy measures, and we separated those organizations based on the level of market influence affecting those organizations.

CLASSIFICATION SCHEME FOR R & D ORGANIZATIONS

LEVEL OF MARKET INFLUENCE (Nature of R & D Products)	LEVEL OF GOVERNMENTAL INFLUENCE: High	Moderate	Low
Generic Product (Low)	Public Generic	Quasi-Public Generic	Independent Generic
Balanced Product (Moderate)	Public Multi-Market	Quasi-Public Multi-Market	Independent Multi-Market
Proprietary Product (High)	Public Market	Quasi-Public Market	Independent Market

Table I

We came up with nine classifications, nine types of research organizations ranging all the way from public generic laboratories, which are laboratories which are heavily influenced by the Government and with only limited influence from the market, ranging all the way to, at the bottom right-hand corner, independent market laboratories, which are laboratories experiencing very low levels of governmental influence and very high levels of influence from the market.

Now you might say to yourself, "Well, 'public generic laboratory' means 'governmental laboratory.' " Well, "public generic laboratory" does not mean "governmental laboratory." It means a laboratory heavily influenced by the Government, that is, producing a product not oriented toward the market, and in that array of organizations what we found was, after surveying these 800 labs, 250 agreed to participate in great detail for us to study them in greater detail. We found that that public generic classification was made up of only about 20 percent Government-owned laboratories, but that the array of organizations producing the types of products which were typically linked to Government labs was actually made up of industrially owned labs, what we call cooperatively owned labs, and a full range of research organizations.

What we found, if you look at the second slide, moving on from slide 1, is that of our 250 study participants—that is, the 250 laboratories that let us in to see what they were doing in great detail—we found a very large number of these organizations classified as public generic labs, only a small number as independent market labs, with a number spread out throughout. Now I'm not certain whether or not the significance of this is as obvious as it is to us, since we have been on the inside. If you look, for instance, at the public market laboratory classification back on slide 1, public market laboratories are laboratories that are heavily influenced by the Government. The results of the classification indicate that each of the R&D laboratories of the various types identified are similar in character, regardless of lab ownership.

CLASSIFICATION OF R&D ORGANIZATIONS BY ENVIRONMENTAL INFLUENCE

LEVEL OF MARKET INFLUENCE (Nature of R & D Products)	LEVEL OF GOVERNMENTAL INFLUENCE: High	Moderate	Low	Row Total
Generic Product (Low)	Public Generic	Quasi-Public Generic	Independent Generic	
Total	121	40	6	167
Row %	72.5	24	3.6	68.2
Column %	89.6	64.5	12.5	
Total %	49.4	16.3	2.4	
Balanced Product (Moderate)	Public Multi-Market	Quasi-Public Multi-Market	Independent Multi-Market	
	4	11	10	25
	16	44	40	10.2
	3	17.7	20.8	
	1.6	4.5	4.1	
Proprietary Product (High)	Public Market	Quasi-Public Market	Independent Market	
	10	11	32	245
	18.9	20.8	60.4	100.0
	7.4	17.7	66.7	
	4.1	4.5	13.1	
Column Total%	135 55.1	62 25.3	32 19.6	

Number of missing observations = 5

Table II

If we move on past the second slide, which gives you some idea of how an array of laboratories in a sort of a test run of this activity might be distributed, and move to the third slide, I know that it's a little bit small but let's look just at research scope. What we did here was, beyond the 250 that gave us detailed information, we actually visited about 35 or 32 of these laboratory sites for extensive onsite case study analysis, and in that I tried to summarize these case study analyses in this particular chart.

R & D Effectiveness Variation by Laboratory Type

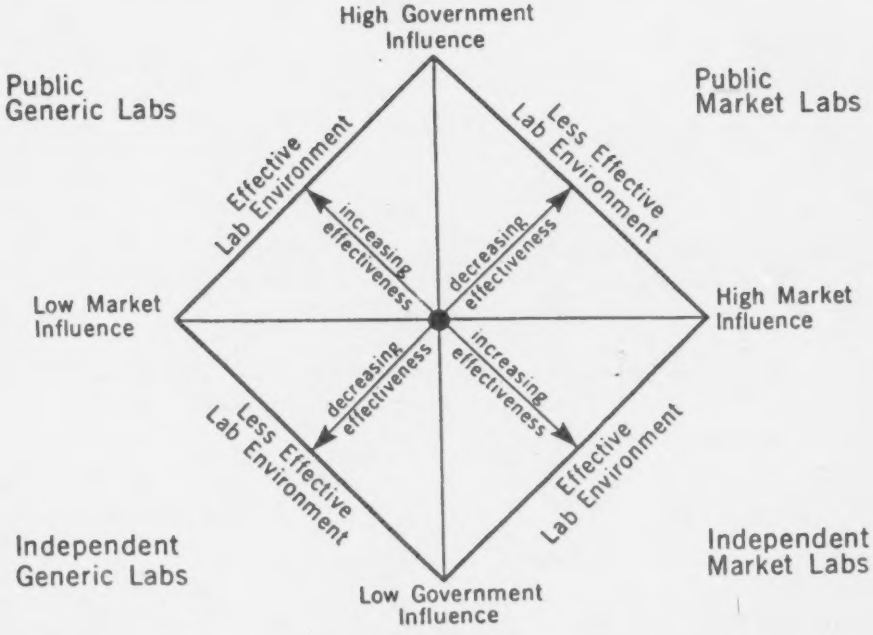


Figure 1

Looking only at research scope, we see, for instance, that public generic labs and quasi-public multimarket labs are the only two types of laboratories that have a national research orientation. Quasi-public generic laboratories, which are laboratories which have a moderate amount of influence from the Government and very little influence from the market, tend to be more regional or, if they are industrially oriented, interfirm in their nature. What this chart implies is that we did find distinctive differences that were consistent among the laboratory types that we were looking at, confirming in fact that our classification technique was capturing the actual evolutionary process that had occurred among this particular organizational population.

We also found, looking at the organizational stability question, that only three of the laboratory types, it turned out, were stable in a sense—stable in the sense of funding, stable in the sense of organizational structure, stable in the sense of planned growth and those types of things. These were the public generic labs, the quasi-public multimarket labs, and the independent market labs. It turns out that if you looked at the archetypical type governmental lab from what we are expecting governmental labs to do, the public generic laboratory classification fits that the closest, and the inde-

pendent market laboratory classification fits the industrial lab the closest. The problem is that ownership—industrial, governmental, university, or whatever—has really nothing to do with any of these classifications whatsoever.

Now the second part of our study was to ask the general question: "How do these various laboratory types, given that we have found that this is a useful means of actually understanding the types of labs that we have, how does their effectiveness vary? Does it vary?"

If you turn to the next slide, the one titled, "R&D Effectiveness Variation by Laboratory Type," I try to summarize a rather extensive effectiveness evaluation there.

ORGANIZATIONAL VARIATION BY R & D ORGANIZATION TYPE

	PUBLIC GENERIC	QUASI-PUBLIC GENERIC	INDEPENDENT GENERIC	PUBLIC MULTI-MARKET	QUASI-PUBLIC MULTI-MARKET	INDEPENDENT MULTI-MARKET	PUBLIC MARKET	QUASI-PUBLIC MARKET	INDEPENDENT MARKET
RESEARCH SCOPE	National Interfirm	Regional Intrafirm	Regional Intrafirm	Regional Intrafirm	National Interfirm	Regional Intrafirm	Regional Intrafirm	Regional Intrafirm	Regional Intrafirm
TYPE OF TECHNICAL CHANGE PURSUED	Revolutionary	Evolutionary	Evolutionary	Evolutionary	Revolutionary	Evolutionary	Evolutionary	Evolutionary	Evolutionary and sometimes Revolutionary
RESEARCH FRONTIER	Scientific and Technological	Achievement and Technological	Technological and Scientific	Technological	Technological and Scientific	Achievement	Achievement	Achievement	Achievement and Technological
TECHNOLOGICAL RESEARCH PLANNING	Multi-year	Annual to Biannual	Annual to Biannual	Biannual	Annual to Biannual	Annual	Annual to Biannual	Annual	Annual
ORGANIZATIONAL STABILITY	Stable	Unstable	Unstable	Unstable	Stable	Unstable	Unstable	Unstable	Stable
ORGANIZATIONAL STRUCTURE	PI Mode	PI Mode	PI Mode	Departmental	Departmental and PI Mode	Departmental	Departmental	Departmental	Departmental

Table III

What we did was, of the thirty-two case study laboratories, we carried out a four indicator effectiveness evaluation. The four indicators of effectiveness of the labs were, we did what we called a significant accomplishment evaluation. We took a list of significant accomplishments from the each of the laboratories, representing each of the various types that we had. We had each of these significant accomplishments evaluated by a peer committee as to their overall scientific or technical significance. We then went to a second indicator, what we call "general peer review," where we had these 32 laboratories evaluated by the general scientific community as to their overall effectiveness.

The third indicator that we had of effectiveness was what we called strategic constituency evaluation. We asked those people around the laboratories, each of them, "Is this laboratory effective, and if it is effective, how effective is it?" We asked that of each of the groups that, in a sense, were stakeholders in each of these laboratories involved in the case study. Then, finally, we did our own effectiveness evaluation—that is, the interviewing team, the site visit team—of what was going on.

What we found is kind of interesting, and I have tried to summarize it in this graphic. What we found was that laboratories with high levels of governmental influence that also had high levels of

market influence—that is, laboratories which were dominantly influenced by the Government, which were also asked to interact with the market—what we found was that their laboratory effectiveness decreased as the level of market influence increased. Looking at the upper right quadrant, the public market labs were the type of lab that fit in that classification, and you can see that from our evaluation, at least for now, given the nature of the way science policy is put together, that laboratory type operates in a less effective environment.

If you look at the public generic laboratory type—that is, if you increase governmental influence while at the same time not increasing market influence—you tend to increase the ability of those laboratories to operate effectively. Looking in the lower right quadrant—moving in the other direction—if you have a high market influence environment with low governmental influence, what some traditionally consider to be the industrial laboratory environment, what we call the independent market labs, that turns out to be an effective environment. But if, on the other hand, looking at the left quadrant, you have no dominant influence either from the Government or the market, what you find is that you also have a decreasing level of effectiveness.

Now that summarizes generally our effectiveness evaluation. Looking at how that plays out at the next slide, the slide entitled: "Research focus of various laboratory types," what we did was, we arrayed each of the laboratory types on this figure according to how they are oriented—the types of research that they do—not basic or applied. That is too linear of a classification. What we look at is the extent to which they devote their research toward the scientific frontier, what we call the technological frontier, which is the most advanced set of technological options, or what some people call the achievement frontier, what I have listed there as existing technological options.

RESEARCH FOCUS OF VARIOUS LABORAORY TYPES

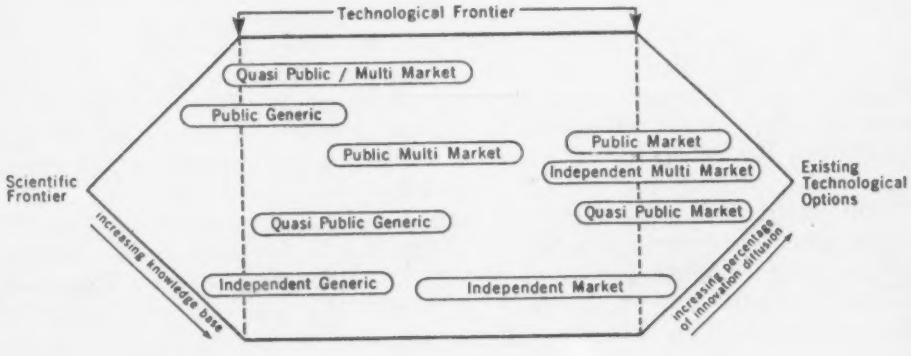


Figure 2

Now remember, of the nine laboratory types that we were able to classify, of the nine types that we captured in our assessment of

how these organizations have changed, only three of those types truly proved to be effective in carrying out their missions—the public generic laboratories, the quasi-public multimarket laboratories, and the independent market laboratories. The other six types on that chart are spread out, and are much less effective than those three.

What that indicates to you is that, if you look at this from a national perspective—and we have a difficult time extrapolating only from 250 laboratories to a national perspective, this is just phase 1 of the study—if you extrapolate that—what that means is that in the area of intermediate applied research, in the area of technology development, in the midrange of the technological frontier—we have a gap. We have an inability to communicate between certain laboratory types, as a result of not having real effective research organizations in that particular arena, operating within that specific arena.

We did look at and consider some of the policy implications of some of our findings, and I won't go into all of them. We have summarized them in a number of comprehensive documents, other than the document that I have presented to the task force, and those are available. The principal document of phase 1 of the study is available through the National Technical Information Service, but let me review some of the points which might be worth considering by the task force.

First, we find that R&D laboratories are not static organizations, static entities which are impervious to change. They are in fact highly innovative organizations which change at rapid rates from an innovative perspective. They change rapidly as a function of Government policy, and it should be remembered that when Government policy is being developed, that the organizations to which these policies are being directed actually do change as a result of those policies. They physically, organizationally, and behaviorally change. I think that's an important point. Policies should be thought of from the perspective that they have more than just an impact on the rate of technological growth or the rate of technological change within a specific industry or a specific sector. They actually cause these organizations to change themselves. They cause evolutionary change, as we have seen since 1940.

Second, we need to seriously consider the question of institutional variation when developing new science or research policies. At present the policies that we have are very generalized. They look at the industrial sector or they look at governmental labs as one block, as one mass of organizations. We are trying to suggest through our new typology that we can't think of them that way. We have got to look at them much more carefully. We have got to consider the conflicting influences of the market and the Government and then think about how that might affect or influence the effectiveness of those organizations to produce the knowledge or the intellectual capital that we are asking them to produce.

Third, as I indicated in my statement, we need to consider the possible effects of increasing the level of market influence on what we call the public generic labs very carefully before we move in this direction on a large scale. Preliminary indicators of phase 1 of our study tell us that public market laboratories and public multi-

market laboratories have a tough time being effective in the U.S. political/economic system. That is, their effectiveness begins to deteriorate as their level of conflict between governmental influence and market influence increases. To some extent, we need to find out why this is a problem and perhaps attempt to address this problem.

Then, finally, my fourth point is that R&D policy initiatives must be cognizant of the influence conflict that I was mentioning just previously between governmental and market influence. We should recognize that Government influence can have a negative effect and a positive effect on the conduct of research, given that we have some understanding of the extent to which these research organizations—what we are actually looking at when we are attempting to implement policy on this range of organizations.

Basically, that is where we have gone thus far in the study. We have been at it for a while, and with that I'll stop.

[The prepared statement of Dr. Crow follows:]

TESTIMONY

of

Michael M. Crow
Assistant Director for Policy Analysis
Ames Laboratory
and
Department of Political Science
Iowa State University
Ames, Iowa

Barry L. Bozeman
Professor and Director
Technology and Information Policy Program
The Maxwell School
Syracuse University
Syracuse, New York

Before the
Task Force on Science Policy
Committee on Science and Technology
U.S. House of Representatives

October 3, 1985

POLICY IMPLICATIONS OF THE EVOLUTIONARY CHANGE IN R&D ORGANIZATIONS

> "Today science in America is conducted within a framework of institutional structures consisting of research universities, industrial firms, and governmental agencies that evolved in part by purposeful design and in part by historical accident." (Report of the Task Force on Science Policy, Committee on Science and Technology of the U.S. House of Representatives, 1984).

Introduction

Mr. Chairman, my name is Michael Crow and I currently serve as the Assistant Director for Policy Analysis at the Ames Laboratory and teach science and technology policy at Iowa State University. This morning, my goal is to address the general question of how R&D laboratories have evolved since 1945, as well as the more specific questions of what do these changes mean for R&D policy. The data I will be presenting was collected under the auspices of the National Comparative R&D Laboratory Project which I directed between October 1983 and February 1985.[1]

The fact that R&D laboratories have evolved and change since the expansion of government R&D policy in the 1940s is taken as a given. We have all observed the changes from the largely pure-type industrial, governmental and university laboratories of the pre-World War II era to the large number of R&D laboratory types operating today. Unfortunately, we have not updated our conceptualizations of these organizations with these changes. It is toward this end that our comments today are directed.

[1]A complete summary of the findings of this project is presented in the report entitled The Effect of Publicness on Organizational Behavior: Comparative Analysis of R&D Laboratories. This report is available from NTIS (Report number 85-216646).

This persistence in sticking with our pre-1940 notion of the institutional framework for R&D organizations (industrial, government and university) not only ignores the evidence of drastic organizational change, it also fails to recognize the very dynamic nature of this particular organizational form. In less than 100 years research organizations have evolved from the small product oriented industrial technical shops of the 19th century to one of the most diverse organizational populations currently in operation. R&D organizations have changed rapidly as a result of the very dynamic environment in which they operate. With over 11,000 R&D organizations operating in the U.S. it has simply become impossible to consider them from the once acceptable industiral/university/governmental framework.

Rethinking the Institutional Framework for R&D Organizations

By rethinking the institutional framework of R&D organizations we may better understand the types of institutions performing the task of knowledge production and also improve our concepts as to how technology changes. Current theories assume that industrial, governmental and university research organizations each have a particular role and function. These assumptions have become so pervasive that they have kept us from fully understanding the extent to which R&D organizations have evolved. In fact, the R&D organization, pursuing the development of new products and processes guided by market forces, has become a rarity. As a result, we have developed over time the misconception that industrial R&D labs are similar and that while some are heavily influenced by the government they predominantly remain guided by market forces. Such an assumption undermines several of the basic precepts of modern organiza-

tion theory which tell us that organizations behave as a function of their environment. Given this fact, we feel it is foolish to believe that an industrial R&D organization influenced heavily by both the government and the market is, in fact, the same type of organization as one operating with influence from only the market.

Given the extensive changes in the level of government influence affecting industrially owned R&D labs, the changing role of market influences on government labs and the wide array of hybrid laboratory forms we feel that the time has come to reconsider the conceptualization of the R&D organization framework. To address this problem we designed and carried out under the auspices of the National Comparative R&D Laboratory Project, an extensive analysis of how R&D laboratories have changed over the last four decades. To capture these differences, a new institutional conceptualization for R&D organizations was designed and tested; the remainder of this paper reviews this effort.

Recommended Organization R&D Typology

To address the problem of evolution among R&D organizations, a new framework for classifying and conceptualizing these organizations, in this case R&D laboratories, was designed. To capture the nature of the effect of changes in the level of governmental influences, while at the same time considering the effect of market influence on an R&D laboratories behavior, a two dimensional configuration was designed which would classify R&D organizations according to their dominant external inputs. Regardless of who owned a laboratory we felt it was important to first classify R&D laboratories according to the extent to which they were influenced by the government. Was a laboratory 'public' in the

sense that it was heavily influenced by the government or was it independent of government influence? Beyond government influence, we felt that the extent to which the products of an R&D laboratory were influenced by the economic market would also be useful in capturing laboratory variation.

With our goal being the design of institutional framework that would capture the changes that had or might occur among research organizations, the nine celled classification matrix shown below in Table I was developed.

CLASSIFICATION SCHEME FOR R & D ORGANIZATIONS

LEVEL OF MARKET INFLUENCE (Nature of R & D Products)	LEVEL OF GOVERNMENTAL INFLUENCE: High	Moderate	Low
Generic Product (Low)	Public Generic	Quasi-Public Generic	Independent Generic
Balanced Product (Moderate)	Public Multi-Market	Quasi-Public Multi-Market	Independent Multi-Market
Proprietary Product (High)	Public Market	Quasi-Public Market	Independent Market

Table I

Each of the nine laboratory classifications represent the general types of R&D organizations that can be expected to be operating in the complex array of government influences and market influences that affect organizational behavior.

As Table I indicates, there are a number of possible R&D laboratory types. Public Generic laboratories, for instance, might be considered to be the archetypical 'government' R&D lab of the pre-1940 era. These are research organizations which are heavily influenced by the government with an R&D product that is generic in nature, resulting in very little market influence. In contrast, the Public Market laboratory type represents those research organizations which are simultaneously heavily influenced by both the government and the market. Organizational logic tells us that while both of these research organization types are influenced heavily by the government, that the variation in market influence is likely to result in a very different type of organizational behavior.

To test the utility of this new conceptual framework for the array of R&D institutions that currently exist, we classified 250 respondents to an extensive survey of 839 energy or energy related R&D laboratories. Based on these responses the laboratories were classified according to their various levels of governmental and market influence. The results of this classification are shown in Table II. While too preliminary to be representative for all R&D organizations, this classification, and the subsequent analysis of similarities and differences in organizational structure, resource flows, R&D product configuration and research focus, indicates that there are, in fact, a wide range of R&D

CLASSIFICATION OF R&D ORGANIZATIONS BY ENVIRONMENTAL INFLUENCE

LEVEL OF MARKET INFLUENCE (Nature of R & D Products)	LEVEL OF GOVERNMENTAL INFLUENCE: High	Moderate	Low	Row Total
Generic Product (Low)	Public Generic	Quasi-Public Generic	Independent Generic	
Total	121	40	6	167
Row %	72.5	24	3.6	68.2
Column %	89.6	64.5	12.5	
Total %	49.4	16.3	2.4	
Balanced Product (Moderate)	Public Multi-Market	Quasi-Public Multi-Market	Independent Multi-Market	
	4	11	10	25
	16	44	40	10.2
	3	17.7	20.8	
	1.6	4.5	4.1	
Proprietary Product (High)	Public Market	Quasi-Public Market	Independent Market	
	10	11	32	245
	18.9	20.8	60.4	100.0
	7.4	17.7	66.7	
	4.1	4.5	13.1	
Column	135	62	32	
Total%	55.1	25.3	19.6	

Number of missing observations = 5

Table II

laboratory types operating in todays policy/market settings. The results of the classification indicate that each of the R&D laboratories of the various types identified are similar in character, regardless of lab ownership.

Subsequent on site analysis of a number of laboratories of each type (32 labs in total) indicated that the method of laboratory classification did, in fact, capture very distinctive differences in structure, resource scope, research frontier, research planning and organizational stability among the laboratory types. Table III summarizes these differences below.

The variation among laboratory types was quite distinctive and indicates that each type conducts its research from its own set of perspectives. The traditional roles of university, industrial and

ORGANIZATIONAL VARIATION BY R & D ORGANIZATION TYPE

	PUBLIC GENERIC	QUASI-PUBLIC GENERIC	INDEPENDENT GENERIC	PUBLIC MULTI-MARKET	QUASI-PUBLIC MULTI-MARKET	INDEPENDENT MULTI-MARKET	PUBLIC MARKET	QUASI-PUBLIC MARKET	INDEPENDENT MARKET
RESEARCH SCOPE	National Interfirm	Regional Intrafirm	Regional Intrafirm	Regional Interfirm	National Interfirm	Regional Intrafirm	Regional Intrafirm	Regional Intrafirm	Regional Intrafirm
TYPE OF TECHNICAL CHANGE PURSUED	Revolutionary	Evolutionary	Evolutionary	Evolutionary	Revolutionary	Evolutionary	Evolutionary	Evolutionary	Evolutionary and sometimes Revolutionary
RESEARCH FRONTIER	Scientific and Technological	Achievement and Technological	Technological and Scientific	Technological	Technological and Scientific	Achievement	Achievement	Achievement	Achievement and Technological
TECHNOLOGICAL RESEARCH PLANNING	Multi-year	Annual to Biannual	Annual to Biannual	Biannual	Annual to Biannual	Annual	Annual to Biannual	Annual	Annual
ORGANIZATIONAL STABILITY	Stable	Unstable	Unstable	Unstable	Stable	Unstable	Unstable	Unstable	Stable
ORGANIZATIONAL STRUCTURE	PI Mode	PI Mode	PI Mode	Departmental	Departmental and PI Mode	Departmental	Departmental	Departmental	Departmental

Table III

governmental laboratories can be seen in the characteristics of the various lab types, but these types have nothing to do with ownership. Public Generic laboratories are clearly based on a 'government laboratory' model of generic R&D products, long range planning, and an emphasis on the scientific research frontier. Of these laboratories, however, fewer than 15% are owned and operated solely by the government. Most are either cooperatively owned and operated or in some cases are owned by industry and financed by the government. In any case, Public Generic Laboratories do have the traits often considered by policy analysts and policy makers to be those of government labs but it is not accurate to call them such. Government owned R&D labs were also found in the Public Multi-Market and Public Market laboratory classifications. Each of these laboratory types behaves with its own individual characteristics, largely as a function of its individual environment. These indi-

istics, largely as a function of its individual environment. These individual laboratory characteristics are consistent among laboratories of the same type regardless of who owns the laboratory.

As a result of our analysis of the 250 R&D organizations involved in the study, it is possible to conclude that we have developed a more accurate conceptual tool for considering the new institutional framework in which R&D is carried out. The classification of R&D laboratories as being either industrial, university or governmental is simply outmoded and in need of replacement.

Today we have research facilities owned by private firms totally financed by the government to produce generic research. Such a research organization can not any more be called a pure industrial research organization than a government financed market oriented facility can be called a pure governmental research organization. The policy arena has become too complex and organizational evolution so pervasive that our 1940 nomenclature no longer applies. This nomenclature is in serious need of replacement and we are offering this approach as a new conceptualization.

R&D Effectiveness as a Function of Governmental and Market Influence

To further test the value of this new institutional framework, we embarked on an effort to evaluate the comparative effectiveness of the various laboratory types. Our basic question was: how does government and market influence affect R&D laboratory performance? This question is, of course, an expansion on the somewhat simpler notion of comparing the performance of a government lab with an industrial lab in a particular area of research. In this case, our desire was to compare the rela-

tive effectiveness of our various laboratory types, giving consideration to the possible reasons behind variations in the relative effectiveness.

The implementation of the effectiveness evaluation involved the extensive study of several labs representative of each of the new types (32 total labs). As a part of this study, four partial indicators of R&D laboratory effectiveness were utilized as a means of gaining some insight into possible variations in performance. These indicators and their measures included:

1) Strategic Constituency Evaluation: The 'stockholders' associated with the activities of each laboratory evaluated, from their individual perspective, the overall effectiveness of the laboratory.
2) General Peer Review: Each study laboratory was evaluated as to its overall effectiveness by at least 30 external reviewers.
3) Significant Accomplishment Review: Each study laboratory identified a number of significant scientific and technical accomplishments produced in the last five years. Each of these were reviewed by at least four external reviewers and an overall evaluation of significant accomplishment outputs was carried out.
4) Case Study Analysis: As a part of the detailed analysis of each of the study laboratories the case study reviewers evaluated the overall effectiveness of the lab. Criteria for effectiveness included 1) funding stability, 2) organizational stability, 3) research planning, 4) new idea generation and 5) general condition of the research environment.

Analysis of the findings of this evaluation indicates that there is significant variation in the effectiveness of R&D laboratories and that much of this effectiveness variation is a function of the various levels of governmental and market influence affecting a given laboratories behavior. The results of this analysis are summarized for ease in interpretation in Figure 1.

As shown, laboratory effectiveness in the production of generic products increases as government influence on the R&D organization increases. As might be expected, effectiveness in the production of

R & D Effectiveness Variation by Laboratory Type

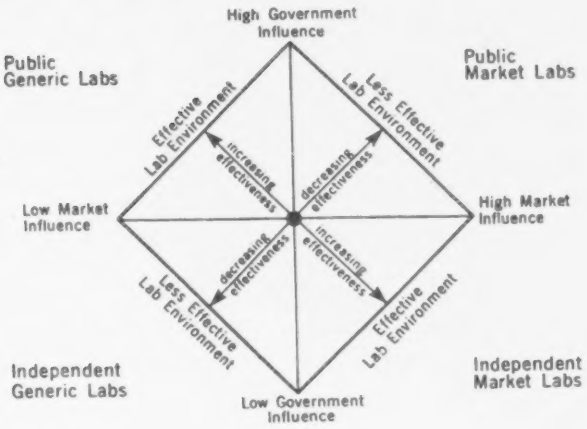


Figure 1

market oriented R&D products decreases as governmental influence increases. Our assessment is that R&D laboratory effectiveness declines rapidly as a function of environmental complexity. In other words, as the government/market influence mix becomes more complicated, the effectiveness of the organization declines. Our explanation for this is that as the influence mix increases in complexity (e.g., the Public Market Laboratory type with high governmental and high market influence) the individual laboratory must deal with a higher level of organizational goal conflict, spend more resources on administration and spend less time in the very important process of research planning. Only Quasi- Public/Multi-Market laboratories were able to balance their competing influences so as to remain effective. All other laboratory types which were not either dominantly influenced by the government

(Public Generic Laboratories) or dominantly influenced by the market (Independent Market Laboratories) experienced a reduced level of measured effectiveness. In addition, those laboratory types with little government or market influence at all (i.e., Independent Generic Labs) also appeared to be less effective. The explanation for this, however, remains unclear.

Policy Implications of Rethinking the Institutional Framework

For the purposes of this discussion, the focus of assessing science policy implications of this reconceptualization is limited to R&D policy. Post-1980 R&D policy in the United States is best characterized as being composed of a number of components. These components include: 1) continued direct support to industry for the conduct of research in areas of national interest and in areas of potential economic growth, 2) general movement of federally financed research and development institutions into a mode where they are more responsive to the market economy and its need for growth, 3) movement toward the development of cooperative centers for research and technology transfer among universities, industry, and government, and 4) R&D tax credits designed to enhance the rate of investment at industrial R&D laboratories.

Considering only the points detailed above as general trends of current R&D policy, the implications of our reconceptualization of the institutional framework for R&D organizations should bring about cause for hesitation, in continuing down the same policy path without careful thought. Consider the implications detailed below with regard to the four policy trends reviewed above.

1) Continued R&D Support to Industry -- The continued direct policy action of R&D funding to industry is based on the assumption that government financing of research in industrial laboratories results in a complimentary integration of the firm's R&D with the government's goals. The basic assumption here is that firms naturally will not invest in research beyond the level of private return and that if the government makes available resources to alter the firm's cost function then the firm will pursue research in areas where it might not normally have been involved.

Our general findings indicate that as firms move away from less complicated environments with very little influence from the government, toward environments which are less directly influenced by their individual market arena, the stability and effectiveness of the R&D laboratory declines. More important than this fact, the fact that government policies for the direct financing of industrial research fail to consider that the addition of government financing to a R&D laboratory with previously low levels of government influence will, in effect, change the nature of that R&D laboratory. This environmental change, it is hypothesized, results in structural and behavioral changes in the R&D laboratory which cause it to become a different type of R&D laboratory. As a result, the rate and direction of scientific technical change previously occurring at the laboratory, in all likelihood, will change to the extent that there is actually an effectiveness decline.

The general findings and subsequent hypotheses resulting from the National Comparative R&D Laboratory Project, therefore, do not support the notion that increasing direct R&D support for industry in fact moves

us toward improving rates and direction of technical change. For instance, it should be noted that Public Generic laboratories, which have the lowest levels of market influence and the highest level of governmental influence, operate the most effectively on the technological and scientific frontiers. It is research which is directed toward these frontiers that results in the revolutionary type of technical breakthroughs desired by many. At the other end of the spectrum, Independent Market laboratories, in environments with low governmental influence and high market influence are also capable of working on the technological frontier. An increase in governmental influence, however, among these laboratories results in a movement away from the technological frontier toward a focus on existing technologies only. Figure 2 illustrates the research focus of the various laboratory types and further details more effective from less effective laboratory types.

RESEARCH FOCUS OF VARIOUS LABORAORY TYPES

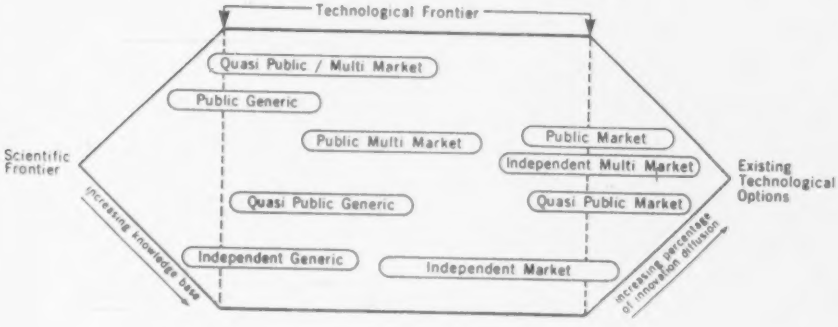


Figure 2

A national R&D policy which assumes that direct financing of research in industrial R&D laboratories will lead to the most effective production of either revolutionary technical change or evolutionary technical change should be cognizant of the implications of our findings which indicate that it is possible that relatively small changes in the level of governmental influence and in the distance a laboratory moves away from its traditional markets could result in very drastic reductions in an R&D laboratory's effectiveness.

2) Movement of 'Public' R&D organizations Toward Market Directed Technical Change -- In the last several years, there has been an outcry for "government laboratories" to be redirected to meet the science-based technical change/economic growth needs of our stagnated economy. The focus of these policy changes has been largely directed toward the Public Generic Laboratory type. As the federal government owns many of these laboratories and finances the rest it has been the desire of many federal policy makers to apply the vast scientific development capabilities available in these institutions to the technical development needs of industry.

The implications of a policy of this type are quite significant. To begin with, Public Generic laboratories appear to have a unique role among the nine laboratory types studied. These laboratories have a national research orientation, a focus on revolutionary technical change, a long-range planning horizon, and a focus on the scientific and technological frontier. In addition, this laboratory type is both stable and among the most effective.

With this background, it is our opinion that Public Generic laboratories in their current environmental setting are quite effective in the production of revolutionary technical change which is not directed toward the needs of any particular industry, but is directed toward particular technological applications. As shown earlier in Figure 2, the production of research and development directed toward the scientific and technological frontier is more effectively carried out in Public Generic R&D laboratories. It is our assessment that as a result of high levels of governmental influence, combined with the lack of market influence these R&D laboratories are able to pursue research agendas with some independence and distance from direct market influence. Our conclusion is that research which might not normally be conducted, due to market influence and constraints, is carried out. Furthermore, this research appears to be both effectively carried out and significant in its value.

The movement of these laboratories into environmental settings with increasing levels of market influence could result in drastic changes in effectiveness and also in the research frontier at which research is conducted. Assuming that governmental influence remains the same and market influence is increased, the laboratory types already existing under these environmental constraints indicate that research effectiveness could drop drastically and that the research focus would move away from the scientific frontier. As a result, from a national policy perspective, the nation's ability to pursue research beyond evolutionary development of existing technologies would be greatly reduced.

3) Development of Cooperative Research Centers -- For some time, it has been the policy of the National Science Foundation and other groups within the government to attempt to stimulate the development of industry/university or university/government cooperative research centers. The assumption here is that development of such cooperative research activities will results in enhanced rates of technical change. Again, this policy assumes that the subsequent environment of the various organizations participating in these cooperative activities will only be positive. Some of the findings of this study indicate that movement toward conflicting market and governmental goals can result in a number of problems. As a result, the development of cooperative research centers as a national policy should be pursued quite carefully.

The objective of any cooperative activity should be the development of an environment of balanced influences where governmental influence is checked by market influence. In addition, and as in the case of Quasi-Public/ Multi-Market laboratories, there must also be the development of a self-determined research agenda. It is through the development of the self-determined research agenda and later the acquisition of resources from either the market or the government that research effectiveness can be maintained. In addition, many of the cooperative activities that have developed in the last several years have grown out of the Public Generic Laboratory type. The movement of these laboratories to new environmental states can reduce our national capability to conduct research directed toward the scientific and achievement frontier. This should be considered in any and all potential policy actions along the lines of cooperative research.

4) R&D Tax Credits -- R&D tax credits are designed to improve the internal calculus of the industrial firm for conducting research and development activities. The hope is that a tax credit will provide sufficient stimulus to permit industrial firms to conduct research, with their own resources, above and beyond that which they might normally have decided to pursue. This general policy seems to have some of the same problems as many of our national R&D policies. To begin with, the assumption is that industrial research laboratories are the principal means through which science-based technical change is produced. The assumption is that if we provide tax incentives to increase the rate of R&D investment in industrial laboratories, then we will subsequently be able to improve the rate and direction of science-based technical change. While is it probably fair to say that R&D tax credits could potentially have an impact on Independent Market Laboratories that exist within an environment of low government influence and high market influence, the same cannot necessarily be said for industrial laboratories that exist in other environments.

It is our assumption that ownership does not predict behavior, but that environment predicts behavior. As a result, this policy, which is directed toward laboratories based on ownership, fails to recognize the fact that the impact will vary as the environment of the laboratory varies. The determination of the nature of the various impacts that such policies might have in various environments is beyond the scope of this study, but a range of impacts can be expected with not all of those impacts necessarily being positive.

Summary

We began this presentation with a general dissatisfaction with the existing conceptualization of the institutional framework for R&D organizations. Suffice it to say that we found the classification nomenclature of industrial, governmental and university R&D organizations to be sorely outmoded. Not only does this conceptualization inaccurately depict how R&D laboratories have evolved through time but it also has adversely affected the process of science policy analysis through its associated organizational behavioral assumption.

Having thrown out both the baby and the bathwater we suggest a multi-dimensional classification scheme for separating R&D organizations according to variation government and market influence. It turns out that this type of environmentally based classification scheme proved to be very useful in identifying nine distinctly different R&D organizational types. These various types of labs capture in a simple way the new array of institutions that makeup the institutional framework for R&D organizations. As might be expected, each of these R&D organization types behave in a prescribed manner, only in this conceptualization the behavioral inputs are based on environmental inputs more likely to influence behavior than ownership alone.

We realize that this effort is very preliminary and that there is a need to test this new framework on a broader scale. In that regard, it is time that we move in this direction and consider on a comprehensive basis the reconceptualization of the institutions performing our societies knowledge producing role. Continued reliance on outmoded theories and assumptions in a policy area of this importance can only add to frus-

tration. Before we can determine how to improve the output of our research organizations we must first understand what they are and how they might react to any action of the government. History has already taught us that these organizations change rapidly. We should learn from this experience and plan the evolutionary development of R&D organizations rather than leaving it up to a series of 'historical accidents'.

BIOGRAPHICAL SKETCH

MICHAEL M. CROW

Michael M. Crow currently serves on the Political Science faculty of Iowa State University and as the Assistant Director for Policy Analysis at the Ames Laboratory, a government owned/contractor operated facility of the U.S. Department of Energy.

A graduate of Iowa State University, Professor Crow received his Ph.D. in science policy from the Maxwell School at Syracuse University. His research focus is in the areas of R&D policy, R&D laboratory management and energy policy. Dr. Crow has previously served as the Director of the National Comparative R&D Laboratory Project at the Syracuse University as the Assistant Director of the Coal Extraction and Utilization Research Center at Southern Illinois University and as the Associate Director of the Institute for Mining and Minerals Research at the University of Kentucky. He is the author or co-author of a number of publications and also edited the manuscript High Sulfur Coal Exports: An International Analysis (1983) and served as co-editor for the manuscript Strategic Management of Industrial Research (1984).

BARRY BOZEMAN

Barry Bozeman is Professor of Public Administration and Director of the Technology and Information Policy Program at Syracuse University's Maxwell School of Citizenship and Public Affairs. Bozeman teaches courses on R&D management, technology policy, and organization behavior. He is currently conducting research projects on corporate strategies for R&D, the impact of public policies on R&D, technology transfer, technoligcal innovation in manufacturing production processes, technological forecasting for robotics, and technology assessment of synfuels energy technologies.

Bozeman is the author or co-author of several books on public management and R&D including, most recently, Strategie Management of Industrial R&D (1984), Investments in Technology: Corporate Strategy and Public Policy (1983), and New Directions in Public Administration (1984). He has contributed articles on R&D policy and organization behavior to many academic and professional publications. Recently published work has dealt with tax incentives for R&D, R&D joint ventures, measuring the effectiveness of public and private R&D labs, use of scientific and technical information in organization decision-making and bureaucratic structures for science and technology policy.

President of the Academy of Management's Public Sector Division, Bozeman is also a member of the American Association for the Advancement of Science, American Society for Public Administration, and the Association for Public Policy Analysis and Management. He is on the editorial boards of The Urban Interest, American Review of Public Administration, Knowledge: Diffusion and Utilization, Administration & Society, and Journal of Accounting and Public Policy. Bozeman has

served as a consultant to a number of private firms and to a variety of federal agencies, including the National Science Foundation, Office of Technology Assessment, the Department of Energy, National Institutes of Health, General Accounting Office, and Oak Ridge National Laboratory.

Before joining the faculty of the Maxwell School, Dr. Bozeman served as Scholar-in-Residence at the National Science Foundation's Division of Information Science and Technology, and was on the faculty of Georgia Tech. In 1983, Bozeman was Visiting Professor of Science Studies and Management, Virginia Polytechnic Institute and State University.

DISCUSSION

Mr. MINETA. Dr. Crow, thank you very much.

First of all, let me, in taking that quote from our own committee as it relates to "purposeful design and in part by historical accident," do you have any idea as to which outweighs the other? Were we really more purposeful or is this whole thing 80 percent accident, where we are right now?

Dr. CROW. I would say that, given that Federal science policy and Federal research policy has not considered the institutions themselves—I mean, the institutions have evolved as a function of their ability to cope with these different environmental influences—I would say that it's predominantly—our array of organizations is more accidental than purposeful, in the sense that we have not sat down and said: "What type of institutions do we want?" In fact, yesterday in some of the discussions there was sort of the hue and cry of: "What type of organizations do we have?" Well, no one could answer that question. There was the hue and cry of, "Well, what can we expect these different organizations to do?" Well, no one could answer that, either.

I think that's an indicator of the fact that there has been a fair amount of random evolution, a fair amount of accidental evolution—you might say—in that there has not been a systematic institutional sort of thread moving through science policy or through research policy. In our attempt to go out and capture how these organizations have evolved, I think we definitely found that.

In that "public generic" classification, for instance, I visited research facilities 100 percent owned by an industrial firm, 100 percent financed by the Government, producing nothing to do with that firm whatsoever, producing nothing to do with the markets of that firm, just producing knowledge. Now do you call that an industrial lab? Do you call that a Government lab? Well, we say you call it a public generic lab. It's heavily influenced by the Government. It's producing a non-market-oriented product, so it is not so influenced by the market, and it is something which has just been allowed to evolve.

If you look out along the array of organizations, I know even within the laboratory that I am a part of the executive council of, given the lack of purposeful policy direction, sometimes I think we set our own course and we evolve on our own. You multiply that by 12,000 organizations out there, and you have got a lot of different entities running around.

So in answer to your question specifically, we are trying to now play catch-up baseball. We are trying to figure out what has happened since 1940. What are these institutions that we have that we rely on so heavily? As Congressman Brown said yesterday: "What do we do with a Jet Propulsion Lab when all of a sudden there is nothing for them to do relative to the Apollo project or planetary exploration? What do we do with this organization?"

Well, first we better have some idea of what it is and what it isn't, and so it has been accidental.

Mr. MINETA. Why was it that your survey was restricted or at least was predominantly energy and energy-related R&D labs?

Dr. CROW. I think because we could only raise $50,000 to do it.

Mr. MINETA. Does that skew what happens in your study?

Dr. CROW. What we have done since we put this together, we think that there would be some change if we increased the organizational population beyond the 839 energy or energy-related R&D labs that we looked at. We think there would be some variation, but not a tremendous amount. We think we would have to modify some of our preliminary findings but not a tremendous amount, so there is a slight skewing but we don't think that it's heavy.

The reason we focused on energy labs was predominantly for the effectiveness evaluation. The effectiveness evaluation was very complicated to implement, and we needed some continuity running through the labs. Previous studies in Europe done by the Science Policy Research Unit at the University of Sussex indicated that the best way to look at research organizations is to at least have some commonality when you're getting started. To have undertaken a more comprehensive evaluation of the larger population would have taken a lot more money and a lot more resources than we had available, given that we had to get our money from different sources, also. It meant that there was some orientation of those sources.

Mr. MINETA. In terms of your summary, talking about the nine classifications, I am wondering whether or not these nine classifications are what you have, the conclusions you came to, on looking at the total array of the structures out there.

Dr. CROW. Well, we built this array from organizational theory. What we did was, organizational theorists in the project went into organizational theory and decided that what we now know about organizations, the best way to classify organizations is based on their environment, based on their environmental influence, because it is the indicator of how these organizations are going to change. It is the best predictor of organizational behavior. Environment is the best predictor of human behavior, often. Environment is the best predictor of organizational behavior. So in that regard we feel that this particular typology that we have put together here and any extrapolations of it, or making it more precise, is in fact a means of capturing organizational evolution that has occurred in the past but also organizational evolution as it occurs in the future.

Mr. MINETA. Now what about, in terms of the structure that you have talked about here? Does that template fit whether it's a scientific R&D lab, maybe even devoted to basic R&D or applied R&D? Is it different as it relates to a medical R&D lab or social, taking into consideration more social-type issues?

Dr. CROW. We would probably limit it to, and the way that we designed it was to limit it to organizations which were actually involved in the conduct of physical science or engineering-related research, more than, let's say, a policy sciences research unit somewhere, that type of thing. We're talking about what you would typically think of as a lab.

Now they can range from lots of different types, of course. We think that there is some general applicability of this particular typology. Basic and applied research, there are both basic and applied generic products. I know that at the laboratory that I am a part of, we produce generic products—that is, not directed to the

market—that are extremely basic and are consumed in the general intellectual literature. We also consume products that are physical themselves. We produce techniques for the production of highly specialized materials, totally unique materials, and we transfer that knowledge—not that technology—we transfer that knowledge generically, not to any specific market purpose, so we think that it does have some general applicability to the population of research organizations.

Mr. MINETA. Now according to your model, Dr. Crow, a program such as the Small Business Innovative Research Program would be counterproductive in small laboratories which were previously under high market influence, and I'm wondering if you have any evidence to——

Dr. CROW. Well, you're talking about—I mean, what I know and the people that I have dealt with relative to that program are generally very small firms, sometimes two or three guys running around who have got an idea. They are generally, at least from the people that I have dealt with—and maybe some that you have dealt with are different—but they are not of an organizational size yet to be classified what we call a research laboratory.

There is sort of a minimum threshold to which this applies, but let's say it's a small firm of 20 people or something like that. To that extent, if they are operating on their own from a market perspective, dominated by the market, that's probably hard to say. I mean, if they are at that threshold of just getting started, perhaps they are actually dominantly influenced by the Government and then secondarily influenced by the market.

One could say, however, that given some of our general findings, that if they were large and the Government did come in—they were dominantly influenced by the market—the Government did come in and increase its level of influence on that organization, we would from our results tend to think that their level of effectiveness would decline. They would now attempt to try to deal with two conflicting types of influences.

Now that doesn't mean that necessarily that's the way it has to be. What that means is that, given the way we look at institutions, given the lack of an institutional threat running through some of our policies, what that means is that is what would likely happen.

Now let me take it to another example. One of the laboratories that I visited that was a public multimarket laboratory had previously been in an environment similar to public generic laboratories. They were a major research facility, a couple of thousand employees, and they were being forced by their particular government to increase their level of market-related activities. They were actually becoming more heavily involved, increasing their level of market influence on their organization.

Well, as they did that they changed in their character. You could see how their organization had changed. You could see how their structure had changed. You could see the extent to which their planning process became more and more short term, the extent to which their planning process became more and more linked to the market, and as that happened their level of effectiveness, as we measured it, decreased. In fact, they would also agree that their

level of effectiveness had drastically decreased from their previous setting.

Mr. MINETA. Dr. Crow, we have a call of the House right now but I am wondering, just very quickly, what about the relative sample size, the fact that you have 32 laboratories?

Dr. CROW. We feel that, given——

Mr. MINETA. Is that really a large enough spread to be able to give you a good idea, in terms of your confidence level, of the testing of those 32 labs?

Dr. CROW. In case study analysis, things like levels of statistical significance and confidence levels and so forth are difficult to state. We think that 32 case studies—given the organizational population that we were looking at, 839 laboratories, of which we had significant information on 250—we think that the 32, given the way that we selected them in each of the laboratory types, does give us the type of confidence in our results to make some of the statements that we're making today.

Mr. MINETA. Dr. Crow, you will be able to stay right now?

Dr. CROW. Sure.

Mr. MINETA. Because we have to go over for a vote, and so the task force will stand in recess for 15 minutes.

[Recess taken.]

Mr. FUQUA. Mr. Brown, do you have any questions?

Mr. BROWN. Dr. Crow, your analysis is, I think, going to be very helpful to us as we look at the matter of research laboratories. There are so many of them. You know, just the Government labs, we are told there are 700 or 800 of them, and unless you can put them in some sort of conceptual framework, it's hard to deal with. I wonder if you could give us some examples that help to define the categories that you have set forth in your chart here?

Dr. CROW. In the public generic laboratory type, some examples—and due to the nature of the effectiveness evaluation, I will probably on a couple of them just give you categories—within the study, if you read the whole study, they are anonymous in the study, the 32 actual case studies. In public generic labs, though, we had, for instance, Government-owned, contractor-operated research facilities of large and small size. We had, in public generic laboratories we had an industrially owned, 100 percent financed by the Government research facility producing a nonmarket product, a product totally for the generic consumption from a knowledge perspective. We also had Government-owned, Government-operated research facilities in the public generic type.

Quasi-public generic laboratories included basically groups which pursued Government funding from a contractual perspective. They weren't necessarily federalized facilities like the public generic laboratories. They were facilities that chased Government money and also had a little bit of industrial money on the side.

I can go through who some of these were, public generic laboratories. For instance, there was the Radiation Laboratory at the University of Notre Dame. That's a research facility on the campus at Notre Dame University which is owned by the Government, operated by the university. We know a lot about those.

Also a public generic laboratory: McDonnell-Douglas Corp. Research Facility in St. Louis, MO, 100 percent owned by the firm,

100 percent financed by the Government, producing a product not related to the McDonnell-Douglas market line, producing a product not related to the operating companies of that particular corporation.

Quasi-public generic: the Accurex Corp. in Mountain View, CA was an example of that. That was a particular laboratory which, like I said, chased Government funding. I am not saying that in a negative sense. That was their business. They were in a research business. The Cyclotron Research Facility at the University of California at Davis.

Independent generic laboratories: the Polymer Processing Institute at the Stevens Institute of Technology in Hoboken, NJ. I mean, there you have a facility located at a university with industrial and university personnel, funded not by the Government, funded by the university and various industrial grants, but industrial grants that had—they weren't to produce a market-oriented product. They were just to produce knowledge. That's an example.

Public multimarket laboratories, there weren't very many of those, and the best example was some of the laboratories in the South Dakota State Geological Survey. I'm talking about places that we actually had as our case studies, places that were actually visited, not just the 250 which answered.

The quasi-public multimarket laboratories, the best example there is the General Atomics Corp. in San Diego, CA—GA Technologies, formerly owned by Gulf. That particular laboratory and that particular laboratory type produce a product which is both directed toward the market—a very heavy, not heavy but moderate market influence—and moderate nonmarket influence, moderate Government influence. It turns out that that particular laboratory type was very effective in what it did. We felt that it was effective because those laboratories were self-determinative. They set their own agenda. They sold their research programs to everyone because everybody wanted them, and that's an example of that particular activity.

Independent multimarket laboratories, here we have very little governmental influence but we have a product being produced for both market and nonmarket end uses. Now I don't think you were here when I was describing what that mean, but we call those environmental influences. An example of that was the Ashland Oil research facility in Ashland, KY. They were attempting to produce a product, both a generic product and a market-oriented product, but they were independent of Government influence.

Public market laboratories, and these laboratories had a very difficult time, very difficult: heavily influenced by the Government, heavily influenced by the market. I'll give you two examples. One was the U.S. Bureau of Mines' research facility in Spokane, WA. That particular research facility produces a product which is essentially for the regional mining industry; that's their orientation.

Quasi-public market laboratories: there I will give you an example of the General Motors-Allison turbine research facility in Indianapolis, IN. Here you have a research facility producing a product which is for the market but at various stages of their product development activity you've got the Government funding the intermediate-range research, GM funding the basic research, and the

Government and GM splitting the cost of the development activities. That in this particular case caused some influence conflict between the Government and the market.

Independent market laboratories, that's your bastion of archetypical industrial firms right there. Let's see. Who did we visit there? We looked at the Kaiser Aluminum Co. facility in Pleasanton, CA, as an example. Typical, what you would think to be your prototypical industrial research laboratory; almost an abhorrence of Government influence. "We don't want too much Government money, maybe just a few projects here and there."

Mr. BROWN. When you use the term "market," are you exclusively referring to the private market and not including the public market?

Dr. CROW. I'm including public and private market.

Mr. BROWN. So that a laboratory like Los Alamos, whose product is, we'll say, the Defense Department—they design nuclear weapons—you would describe that as a public market oriented——

Mr. CROW. Well, Los Alamos wasn't 1 of our 250, or I could give you a better answer.

Mr. BROWN. You didn't categorize it?

Dr. CROW. For one, their only product is not that particular thing. They probably have a balanced-type product. They probably are a public multimarket facility. The proprietary nature of the product, which is what makes it have a market characteristic—and I think your point is very good that there are proprietary markets both in the private sector and the public sector——

Mr. BROWN. Correct.

Dr. CROW. The U.S. Coast Guard research facility, working primarily on engine development and other types of things in Groton, CT, is an example of a public market facility.

Dr. BROWN. How would you describe the National Bureau of Standards, which was our first general-purpose research facility?

Mr. CROW. You're asking me to guess, because I have to guess as to what all of their products are and what their dominant orientation is, but what I know about their dominant orientation is that they are probably a public generic facility. In fact, their chief economist, Gregory Tassey, put together the article from which I take the nomenclature of generic technology research and what he calls also infra-technology research, and he has spent some time looking at NBS and its role, so they are probably a public generic research facility although, you know, they've got things going on in Colorado and all over that I don't know a lot about.

Mr. BROWN. Well, the facility in Colorado is probably closest to the public generic research thing.

Dr. CROW. You're hitting on another point. If you look at a specific organization like the National Bureau of Standards, we couldn't classify the organization. We would have to go to their distinctive laboratory units, and I think that one of the problems in some of the generalized science policies is that they assume that all of the units within a single agency are close to being the same. Well, they're not.

We did look at, if you look at, let's say, a company like Gulf, Gulf has 38—or did, before they got wiped out or whatever happened to them—they had 38 research facilities. Each of those research facili-

ties are doing a different thing, and each of them would have to be classified in this typology independently. So some of the NBS—I would say most of the NBS facilities would be public generic type, but there might be some that I'm not aware of that aren't.

Mr. BROWN. Thank you very much, Mr. Chairman.

Mr. FUQUA. Mr. Lujan.

Mr. LUJAN. Thank you, Mr. Chairman. I'm sorry that I'm late. There is a correlation here that is rather interesting. We are all looking for stability, you know, and doing the right thing at the right time. It is interesting that all of those that by type of technical change pursued are revolutionary, also are stable, and those are the only ones.

Dr. CROW. Well, in the independent market I think I say that they are both revolutionary and evolutionary, do I not?

Mr. LUJAN. Yes. Yes, you do, but it includes the revolutionary portion.

Dr. CROW. Yes. It is an interesting——

Mr. LUJAN. Give me—I'm sorry I was late—what are you talking about when you're talking about "revolutionary"—just whole new products, whole new——

Dr. CROW. No, it's an orientation. In the larger things that I have put together, in the literature there are two dominant types of technical change which occur within research organizations. There is technical change which is, in a sense, search-induced. That is, the laboratory goes about its business by looking at the possible array of alternatives to any particular general question or specific question and searches, from that possible array of technological options, for an option that can be applied to a specific activity, or they actually try to develop that option. They go through a searching process.

The other type of technical change which has been talked about quite a bit by the economist Paul David is what is called local neutral. That is, it is evolutionary in the sense that it is directed toward existing technology and moving existing technology—most technical advance takes place of that type—moving it along step-by-step, taking the light bulb and making it better from what Edison had in 1878. That's local, neutral, evolutionary change. That's the separation.

Now these are broad course separations that we're talking about here. That doesn't mean that each of these laboratories, that that is all that they do. It means that is their dominant orientation, but those are some of the differences. For instance, the laboratory that I am associated with is probably a public generic laboratory involved in revolutionary type change. We are not looking at specific technologies. We are looking at the search process for entirely new technologies.

Mr. LUJAN. So you would then say, if you look at the mission—you were talking with Mr. Brown about Los Alamos, and I know you didn't go there——

Dr. CROW. Right.

Mr. LUJAN [continuing]. But you would know the mission. They were revolutionary in the Manhattan project times when they were looking for a whole new way of doing things, and now—if you just take that, the weapons part of the business—

Mr. CROW. Right.

Mr. LUJAN [continuing]. And now they are evolutionary because of ways to make them go faster and more accurate and that sort of thing. Is that your——

Dr. CROW. That's a good analogy. Let's not pin it on Los Alamos.

Mr. LUJAN. No, no. I understand that. No, I was just talking about that particular——

Dr. CROW. Yes, that's a good analogy. That technology, when it was initially developed, when it moved from science to technology, was what the literature generally calls the revolutionary process, and since then it has been an evolutionary process.

Mr. LUJAN. Why are revolutionary ones more stable? Is it because when a company puts money into—basic research I guess would be more revolutionary than applied science——

Dr. CROW. Not necessarily, but——

Mr. LUJAN [continuing]. That they were going to put up $25 million and we're going to forget about it, you know, not return?

Dr. CROW. What you're looking for is the linkage between stability and——

Mr. LUJAN. Yes.

Dr. CROW. It's hard to say whether or not the two are linked. They are independent variables. I think the more important variable is that each of those three laboratory types have the following characteristics. In the public generic laboratory types you have what I call minimal environmental influence conflict. You do not have a conflict going on within the laboratory structure itself in trying to deal with these conflicting influences of the market and the Government.

In the case of the quasi-public multimarket labs, you have the only laboratory type of all of the nine which exists in a highly balanced environment where Government influence and market influence are relatively the same. It is a balanced environment and then also they are determining their own, they are setting their own agenda. Then finally in the independent market you've got the market influence as the dominant.

Now what happens as you move around that and change that influence perspective, you change the ability of those organizations to remain stable. They are highly conflict-oriented organizations. The public market laboratory organizations were organizations that were highly politicized in their research operations. They were highly—they had large administrative structures devoted to managing this complex environment. They were devoting larger percentages of their resources to what I call environmental scanning and environmental management, trying to deal with these conflicts, whereas public generic, independent market, and the one in the middle weren't doing that. What that meant was that they were able to move on to some of these search-type technical change activities and also they were much more stable type organizations.

Mr. LUJAN. Could you draw the conclusion, then, that in our authorizations that we refrain from managing departments by saying, "You will develop a better battery, you will develop this kind of engine, you will develop the different things," that we direct that agency to do that? Can you draw that conclusion from——

Dr. CROW. Not that conclusion, because to say, you know, "Develop us a better battery," well, you know, there is a lot of different ways that one could go relative to that. To say, "Develop me a better battery industry in eastern California," or something like that——

Mr. LUJAN. Or in New Jersey.

Dr. CROW [continuing]. Wherever, now that's a different question, because then the market influence then dominantly comes to play. I mean, if you're just going to develop a battery, there are a lot of things related to that, if you develop yourself a generic battery, but if you're saying to someone like Oak Ridge National Laboratory, "Help develop the economy of the State of Tennessee," you better do that very carefully. You better think about that very carefully because that particular effect on that particular institution is not going to be minor. It's going to be significant, and I think we need to think about quite a bit more this institutional variable. I guess my dominant point is that the institutional variable in most of your policy development activities, most of the Congress' policy development activities, it is considered to be exogenous. It's outside. Well, it needs to be brought inside. It needs to be considered, and we need probably a lot more information than what I'm giving you here to be able to make some firm type statements as to policy A or policy B.

Mr. BROWN. Would the gentleman yield to me at that point?

Mr. LUJAN. Yes.

Mr. BROWN. The issue here is fairly fundamental. The thrust of what you're saying is that if we take a public generic research institution, for example, and try and move it in the direction of a public market, we lose efficiency.

Dr. CROW. According to the ones we looked at, drastically.

Mr. BROWN. Yes, and yet we have some examples of extremely efficient or productive private research laboratories which combine these functions. I am thinking of Bell Labs, for example, which combines the characteristics of independent generic research, relatively unfettered, looking at opportunities in the scientific world, and then it has as part of its components, independent market, which looks at the potential market opportunities for specific kinds of applied science, and they seem to benefit from being within the same institutional framework, which I gather is fairly carefully managed to promote interaction of the various aspects of it.

I am wondering if this doesn't lead us in the direction of concluding that we don't want to distort an institution which is doing well as a public generic research institution but we might want to link it with something with a different mandate that is more oriented toward the market, if that's the direction that we want to——

Dr. CROW. If I was thinking in that direction, which we're just now getting to the stage where we're going to do that, that's probably a good place to start, and that is to begin to think about the different roles that these types of institutions might assume and then look and say to yourself, "Okay, do we want some public market laboratories?" In Europe there's tons of them. They're all over the place, lots of European industrial research institutes, funded by the Government, that are essentially taking care of

market failures and doing research for particular industrial sectors.

If that's what we want, if we want some public market laboratories, we need to think about those influence conflicts that naturally will occur between the Government and its policies and the market and its natural tendencies, and perhaps think about what are the best types of institutions that can maybe perform in that arena or specially design institutions that can better perform than perhaps the ones that we have there now.

Mr. BROWN. Well, the problem we're running into here is illustrated by the so-called Keyworth Initiative to help the steel industry. They want to link some very good public generic laboratories with the needs of—we might call it an ailing industry——

Dr. CROW. You might call it that.

Mr. BROWN [continuing]. And see if there can't be a fruitful interaction. Now that's the kind of judgments that we have to make. What is the best way of harnessing two disparate kinds of activities in a way that will not degrade the efficiency of the public generic laboratory but which will help to solve the problems of the ailing industry, if it's appropriate to solve it? Now we're not clear in what circumstances it is appropriate to solve it in every case but we need, if we decide to, to do it in the best possible way, it seems to me.

Dr. CROW. Right, and I think that what we have to search for are those special—either special institutions that can operate in these environments that we all know exist out there, or the type of bridging mechanisms that you are talking about between the already effective public generic lab and the already effective independent market lab. There can be bridging mechanisms without pulling either one of them away from their already stable, effective settings, and those are the types of things perhaps that one needs to think about.

Now perhaps I am overgeneralizing here because you're taking us way out into a range of institutions that— personally I don't know a lot about the Bethlehem Steel research facilities, or United States Steel, those types of things. I don't know where they might—what type of institutions they are. I don't know if they are independent market research facilities themselves. Maybe someone else does.

Mr. LUJAN. Let me ask just one final question. I know that we're limited in time, but to understand, what do you mean by "stable"?—stable funding, people generally remain at the laboratory, or what——

Dr. CROW. We looked at stability over a number of variables. One variable had to do with funding patterns, looking not only at funding decline, at organizational patterns, at turnover patterns within the organization from a turnover perspective, at their planning patterns, how they planned, over what period did they plan, and to what extent did they stick within their at least generalized research plans, not that research organizations can plan always what they are going to do, but the extent to which they were able to do that. Also, stability as a function of leadership roles within the organization—there were a whole range of variables that we looked at.

Mr. LUJAN. Thank you.

Thank you, Mr. Chairman.

Mr. FUQUA. Dr. Crow, thank you very much for being here today. We appreciate your contributions.

Dr. CROW. All right. I would be happy to answer any other questions that you might have.

Mr. FUQUA. We may have some written questions that we may wish to submit to you for answer.

Dr. CROW. OK.

[Answers to questions asked of Dr. Crow follow:]

ENERGY & MINERAL RESOURCES RESEARCH INSTITUTE

IOWA STATE UNIVERSITY Ames, Iowa 50011
123 Office & Lab Building
(515) 294-2785

RECEIVED
OCT 25 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

October 21, 1985

Congressman Don Fuqua
Chairman, Committee on Science & Technology
US House of Representatives
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Congressman Fuqua:

This letter is in response to your October 11, 1985 communication and attached questions regarding my testimony of October 3, 1985 before the Science Policy Task Force. My responses to your questions are detailed below.

1. One of the components of post-1980 R&D policy which you did not mention in your testimony is the attempt to stimulate joint venture research. What are the implications of your study with regard to joint venture research?

In many ways, the National R&D Policies which have recently been developed are directed toward stimulating joint venture research and in my opinion operate from a Schumpeterian hypothesis that oligopolistic type organizations are the optimum producers of research and development product. These policies do not recognize that the R&D laboratory of the various firms or organizations involved in joint venture activities are each a part of a distinct environmental setting.

This environmental setting does not necessarily have any correlation with the environmental setting of the parent organization. As a result, the laboratories actually conducting R&D as a part of the joint venture, exist within an environmental setting which is very different. Differences between these environmental settings results in great similarities in expectations and research direction of the various partners. These differences should be considered when designing R&D policies calling for joint research and development activities. In addition, it should be recognized that joint venture R&D activities may result in changing environments. For instance, an R&D laboratory that becomes involved in a joint venture activity that previously has not experienced much market influence could find itself moving toward a new environmental setting, and as a result experience changes that could affect not only the joint venture but the parent organization itself.

The main point here, is similar to the one made in my testimony, and that is that all R&D policies must contain some institutional thread. Institutions and their propensity to be

changed by the various policies that are suggested by the government should be considered when these policies are designed. In that regard, joint venture research policies should consider the fact that increasing the market influence on laboratory partners, who have previously not been influenced, could change how those organizations are likely to perform. One might consider special organizational arrangements to deal with the increased level of market influence that will be experienced by all organizations participating in joint venture research and activities.

2. How many public generic laboratories were rated in effectiveness out of your 32 laboratory sample, and how many of these were federal laboratories?

Of the 32 laboratories involved in the case study analysis, 5 were classified as public generic laboratories. These 5 were drawn from the 121 survey respondents who were classified as public generic laboratories. Of the public generic laboratories which participated in the case study phase of this study, one was an industrially owned and government financed research facility, three were government owned, contractor operated research facilities and one was a government owned, government operated research facility. It must be remembered that the government facilities, both government owned contractor operated and government owned government operated were also studied in the public multi market classification and the public market classification. The point is that all government laboratories are not public generic in their character. Of the 250 laboratories involved in the more general phase of the study, 41 were owned by the government, 46 were owned by an industrial concern, 140 were cooperatively owned by some combination of universities, government or industry, and 23 had mixed ownership status, that is they had portions of their facilities owned by one entitity and other portions owned by another entity. Each of these four laboratory types were dispersed throughout each of the new classification cells. There was a concentration of the government owned facilities in the three public laboratory types. The cooperatively and mixed owned laboratories also had a tendency to be classified public but there was a much greater distribution of these facilities among the new laboratory classification typology.

3. Of the federal laboratories rated in effectiveness, was there a significant variation in the effectiveness evaluation scores, and if so, how do you account for these variations?

Of the federally owned and operated laboratories and federally owned, contractor operated laboratories there was a significant variation in the effectiveness evaluation scores. Among the public generic laboratories, those laboratories which were federally owned and federally operated were slightly less effective than those laboratories which were federally owned and contractor operated. Among the federally owned and federally operated laboratories of the public generic

classification, the public multi-market classification and the public market classification, those laboratories which were federally owned and federally operated tended to have a lower level of effectiveness. It is, however, important to point out that this general tendency in effectiveness variation was for the most part a function of increase in market influence. It appears that among those federally owned federally operated research facilities which were also heavily influenced by the market we observed the lowest level of effectiveness. I believe that this was a result of the extremely difficult time that these laboratories had in managing their market influences as well as dealing with their role as government employees. Those laboratories which were federally owned and federally operated appeared to have an easier time in dealing with the market/government influence conflict problem, and in those areas where conflict was not as significant these laboratories also appeared to be more flexible. Again, the point here is that federal R&D laboratories did appear to be adversely affected by high levels of market influence, particularly when these laboratories were staffed by government employees.

4. Was there a significant variation in the effectiveness scores of the given agency laboratories, and if so, how do you account for these variations among a given agencies laboratories?

We did not conduct enough studies on laboratories within a single agencies sphere of influence to answer this question. We hope in the second phase of this study to deal with a much larger laboratory study population.

5. Of the federal laboratories rated in effectiveness, which were most effective, government owned, government operated or government, contractor operated laboratories? How do you account for the differences in effectiveness between these two types?

As I indicated in answer to question 3, in general the government owned, contractor operated laboratories were more effective. This was due to a number of variables, each of which is difficult to weight, but include the following: 1) lower levels of centralized agency control on scientific decision making, 2) lower levels of politicization in laboratory management activities, 3) a higher level of self determination in the research agenda setting process, 4) less involvement as a technical policy support group, 5) government owned, contractor operated laboratories were viewed as having particular contractor related strength or weaknesses that had developed over time, and as a result were viewed as semi-autonomous entities, 6) government owned contractor operated research facilities had substantially greater flexibility regarding personnel functions and organizational structure. There are, of course, other possible explanations, but in general these points summarize the major differences that we observed.

6. Of the federal laboratories rated in effectiveness, which were most effective, multi program laboratories or single purpose laboratories? How do you account for the differences in effectiveness between these two types?

The total number of multi-program and single program laboratories that were visited was not large enough to make any definite conclusions, but I do have some preliminary thoughts. In general, the multi-program laboratories were evaluated as being more effective in their ability to produce significant technical accomplishments and their general review by peers. Single program laboratories fared well within their own strategic constituency groups as well as in our own analysis of internal processes. What this means is that multi-program labs were deemed as being more effective for comprehensive scientific and technological activities and that the single purpose labs, while not viewed as being ineffective were less well known and therefore, seen as being less effective by many of our evaluators. Across the board, of all the facilities that we looked at those facilities which were larger in scope, with a number of program areas in general were observed as being more effective. The differences in effectiveness are linked again to the ability of the laboratories to work away from being extensively controlled by a single program within an agency or a single agency itself. The multi-program laboratories are institutions which put together their own research agendas and then to a large extent, these research agendas are supported by a number of different sources. From this type of funding pattern, these organizations are able to develop substantially greater flexibility as well as lower levels of bureaucratic control on their behavior, in the end possibly resulting in their lower levels of effectiveness.

I appreciated the opportunity to participate in the Task Forces' information gathering phase and would be happy to assist you in whatever way possible in any of your future tasks. Please don't hesitate to call on me in that regard.

Sincerely,

Michael M. Crow

Michael M. Crow
Assistant Director for Policy Analysis

MMC/lk

PANEL: SCIENCE IN THE U.S. DEPARTMENT OF AGRICULTURE

Mr. FUQUA. We will now begin with our panel of witnesses who will discuss science in the Department of Agriculture. We have two witnesses from the Department of Agriculture, Dr. Terrence B. Kinney, Jr., the Administrator of the Agricultural Research Service, and an old flying buddy of mine, Dr. John Patrick Jordan, the Administrator of the Cooperative State Research Service, and our third panel member is Dr. Keith Huston, Cochairman of the National Agricultural Research Committee and Director-at-Large of the North Central State Agricultural Experiment Station Directors.

Dr. Kinney, we will begin with you. We will make all of your statements a part of the record. If you wish to summarize them, that will certainly be permitted, and then after you are all completed, then we'll go into a question and answer session.

STATEMENT OF DR. TERRENCE B. KINNEY, JR., ADMINISTRATOR, AGRICULTURAL RESEARCH SERVICE, U.S. DEPARTMENT OF AGRICULTURE, WASHINGTON, DC

Dr. KINNEY. Thank you, Mr. Chairman. I appreciate the opportunity to be here, and I will summarize my statement as concisely as possible.

I am Administrator of the Agricultural Research Service of the Department of Agriculture. To begin with, Mr. Chairman, I think it is important that I spend just a few minutes discussing what we perceive as and have in fact had published, that is, the mission of the Agricultural Research Service. That mission is to plan, develop, and implement research that is designed to produce the new knowledge and technologies required to assure the continuing vitality of the Nation's food and agricultural enterprise.

As a Federal research agency, we address problems of legitimate national concern, we conduct research that is appropriate for the Federal Government, and we exploit the unique capabilities of ARS scientists and the facilities that they operate. This is a combination that forms an integrated and coordinated national resource that is not duplicated by other research groups in the U.S. agricultural research and development system.

More specifically, ARS conducts research that is national in perspective, in that it focuses on significant problems affecting the entire Nation, or at least a significant geographic portion; research that is sufficiently long-range, high-risk, and of such broad scope as to require unified planning, continuity of effort, and a stable scientific environment that is maintained by Federal research laboratories; third, research that is not undertaken by other agricultural research institutions; fourthly, research that is uniquely a Federal responsibility, in that it is requested by Congress or the executive branch, it requires a structure ready to respond to emergency situations, in many cases it is international in nature, it supports the development and maintenance of important national collections, such as collections of seeds or insects, and so forth, and research that supports Federal action programs.

The research necessary to accomplish the goals inherent in our mission is conducted at about 140 locations throughout the United

States, and some of these locations are designed to address problems that are very specific in nature. Other facilities, such as our Beltsville facility which employs about 350 scientists, have a wide array of programs that are best addressed by a multidisciplinary approach, and they require equipment and facilities for many scientific disciplines and activities. The ARS facilities are located throughout the United States and in eight locations overseas.

Obviously this tremendous research effort requires constant, comprehensive monitoring, so that shifts of emphasis, redirections of programs, and additional research focus can be done in an orderly and timely fashion. Toward this end, we recently developed the ARS program plan which outlines research possibilities for the next 20 to 50 years, along with a companion document, a 6-year implementation plan that identifies research areas for increased or decreased emphasis in the next 1 to 6 years, and this program is updated at least once every 2 years.

Mr. Chairman, priority-setting is complex and is dynamic. It's an interactive process among staff and line scientists, and includes considerations of both the scientific community and research users. Decisions by the Secretary of Agriculture, the Office of Management and Budget, the Congress and others, determine the ARS appropriation and can affect the allocation of funds to specific locations and areas of research.

However, within ARS, individual scientists, along with our area directors and their staffs, significantly influence priorities based on their analyses of the needs for equipment, facilities, and for personnel for exploiting scientific opportunities. Outside of the ARS, there are many groups, such as the Joint Council, the Users Advisory Board, and many other Federal environmental and other Federal agencies that impact on our planning and priority-setting process.

For the setting of priorities I rely on the Deputy Administrator and the national program staff to plan, to articulate and evaluate the national ARS programs. The national program staff, working with our line organization and all other groups that interact with us, identifies research opportunities that are conducted by other organizations and research needs that are expressed by all of the groups I identified earlier, and those recommendations are identified throughout the year in action memoranda, in option papers, budget analyses, budget preparation, summaries of program reviews, and many, many other documents.

The criteria for setting priorities and allocating resources are outlined in the complete statement, and I won't go through those now. Several factors may constrain the allocation of resources and the kinds of research that ARS conducts, and limit in many ways the flexibility in resource use.

The following factors, which include major constraints, must be considered continually by ARS: one is the availability of scientific expertise; another, the limitations of geography, climate, and soil. Very often research must be conducted in a number of different geophysical locations in order to have meaning. The nature of the problem obviously is important, because sometimes very costly facilities or equipment or special scientific expertise are required. The sequential nature of research is important to consider in priority setting. Sometimes we can't do one piece of research until we

have completed some other. And then the continuous adaptation of biological systems is important and creates new research problems as we solve one—that is, through the development of resistance of plants and animals and so forth.

No totally objective formula is possible for setting priorities and allocating resources for research. Priority setting for research is the exercise of informed judgment. It is based on pertinent criteria and given constraints. At the project level, scientific criteria and experience will predominate. At the national level, scientific criteria must be balanced with Federal policies and with the needs of action agencies and other users of research who are represented at the national level.

Part of achieving that balance and providing the environment for creative research is assuring our scientists the use of the new tools of the trade. Several new technologies are emerging from recent research in the biosciences, particularly advances in molecular biology in the 1960's, and ARS fully supports the use and development of these new technologies to help find solutions to some of the vexing and intractable problems that have faced U.S. agriculture. Called biotechnology, this still-growing field now offers unprecedented opportunities to study and understand the fundamental life processes precisely. Many universities and industrial organizations treat biotechnology as a separate priority. However, ARS chooses to use biotechnology research throughout much of its total program as part of its arsenal of tools in fulfilling its specific mission and program goals. ARS does not concentrate its biotechnology research at specific centers, nor does it plan to do so. In fact, the 5 percent of the ARS fiscal year 1985 funding specifically devoted to biotechnology research is distributed among 200 scientists at 41 different locations. The ongoing biotechnology research is directed toward the solution of high priority agricultural problems of national scope. These include things like conserving and maintaining the quality of natural resources, reducing high costs of farm production, improving crop protection and production efficiency, and so forth.

ARS formally reviews each research project at least once every 3 years, and I will simply complete this by saying that the review process is very complex and involves the best scientific expertise available. It's an ongoing process, and the 3 years is at least at a minimum. Many of our projects are reviewed each year, some of them on a 3- to 6-month basis.

Proposed new research projects compete for available program funds. Each proposed new project is reviewed by peer scientists from the agricultural science community to determine whether or not it should be implemented, regardless of what the funds are earmarked for. One very effective method of reviewing research focuses on the scientist who carries it out, and I simply want to say here that the Agricultural Research Service has the most sophisticated research grade evaluation system of any organization in the country, in my opinion. It is one of the few Federal agencies that has a peer review process for evaluating our scientists, and this is probably the most effective means of determining whether or not research is good, bad, indifferent, or should be continued.

The Agricultural Research Service strongly supports the separate personnel system for scientific and technical personnel proposed by the Federal Coordinating Council for Science, Engineering, and Technology—the committee known as FCCSET—that would change legal and regulatory barriers inhibiting our hiring and retaining scientific stars and superstars. If we are going to retain the best scientists, we have got to be able to reward them.

The use of postdoctoral fellows is another excellent mechanism that ARS uses to bring new ideas, capabilities, and techniques to ARS research, and we aggressively pursue these advantages. The Agricultural Research Service's research associate program, funded from the Administrator's office, has grown from 25 positions in 1984 to 50 in 1985, and we have approved the funding of 100 of these in 1986. There are at present some 250 other postdoctoral scientists throughout ARS. In addition, ARS has a fellowship program which provides opportunities for our research scientists and our administrative personnel to participate in programs up to one year in research or education at an accredited domestic or foreign educational institution or research facility.

Those new ideas and capabilities continue to be necessary to ARS as we maintain our emphasis on mission-oriented fundamental, long-range, high-risk research to solve specific problems. For several decades, as you know, the generation of fundamental agricultural knowledge—the seed corn, if you will, of technology—has not kept pace with its exploitation into useful technology. That knowledge has been used to solve relatively tractable problems at the expense of generating the new knowledge needed to solve resistant problems. Helping to fill the knowledge gap is clearly a Federal research responsibility, particularly in those rapidly advancing areas that offer potential for increasing agricultural productivity.

Finally, gentlemen, the mission, the planning, the priorities would mean little unless research results reach those who need and use them. We not only work very closely with other agencies of the USDA and the Federal establishment but also with the private sector. Last year we had more than 60,000 contacts with business and industry to transfer our technology to the private sector. These are one-on-one contacts between our scientists and industry. Many of these contacts were face-to-face discussions. The national program staff met with no fewer than 150 industry and commodity groups, and I participated in 30 of these sit-down sessions where we, eyeball-to-eyeball, talked about research and research priorities. These discussions and contacts help to keep our 2,650 scientists operating in the real world, and we expect to continue them.

For the reference of the task force, Mr. Chairman, I have several documents—our mission statement, our program plan, and so forth—that will be made available to members of the committee, and I will be pleased to respond at the appropriate time to any questions. Thank you.

[The prepared statement of Dr. Kinney follows:]

STATEMENT OF

DR. TERRY B. KINNEY, JR.

ADMINISTRATOR

AGRICULTURAL RESEARCH SERVICE

U. S. DEPARTMENT OF AGRICULTURE

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

OCTOBER 3, 1985

Mr. Chairman, I am Terry Kinney, Administrator of the Agricultural Research Service (ARS) of the Department of Agriculture and I appreciate the opportunity to be here today to discuss with the Task Force the issue of the current and future role of our Federal laboratories in the conduct of research to continue and to further enhance this Nation's agricultural well-being.

To begin, Mr. Chairman, I think it is important that I spend a few minutes discussing what we perceive as--and have, in fact, had published--the mission of ARS. That mission is to plan, develop, and implement research that is designed to produce the new knowledge and technologies required to assure the continuing vitality of the Nation's food and agriculture enterprise. As a Federal research agency, ARS (1) addresses problems that are of legitimate national concern, (2) conducts research that is appropriate for the Federal Government, and (3) exploits the unique capabilities of ARS scientists and the facilities they operate--a combination that forms an integrated and coordinated national resource that is not duplicated by others in the full U.S. agricultural research and development system. Each ARS laboratory has a defined mission which is consistent with its appropriate role within ARS and the R&D community as a whole.

More specifically, ARS conducts research that is--

1. National in perspective in that it focuses on significant problems affecting the entire Nation or its several broad geographic areas;

2. Sufficiently long range, high risk, and of such broad scope as to require the unified planning, continuity of effort, and stable scientific environment maintained by the Federal research organization;

3. Not undertaken by other agricultural research institutions because of their narrower geographic focus or shorter term perspective; and

4. Uniquely a Federal responsibility in that it--

   a. Is requested by Congress or the Executive Branch and requires special skills, facilities, or capabilities of ARS;

   b. Requires a structure ready to respond to emergency situations of regional or national significance;

   c. Is international in nature, supporting foreign policy initiatives of the U.S. Government;

   d. Supports the development and maintenance of important national collections that are essential to scientific activities; or

   e. Supports Federal action programs.

The research necessary to accomplish the goals inherent in our mission is conducted in 140 locations. Most ARS facilities are owned and operated by ARS, but several locations are provided by the U.S. General Services Administration or are leased. Some locations are designed to address research problems that have a very specific focus. Other facilities such as the large 350-scientist facility at the Beltsville (Maryland) Agricultural Research Center (BARC) have a wide array of programs that are best addressed by a multidisciplinary approach and require equipment and facilities for many scientific disciplines and activities. ARS facilities are located throughout the United States and overseas so that problems of regional, national, and international nature can be addressed under the most favorable research environment. Many are located on university campuses and State agricultural experiment stations because of a unique opportunity for cooperation and interaction with State scientists.

This tremendous research effort requires constant comprehensive monitoring so that shifts of emphasis, redirections of programs and additional research focus can be done in an orderly and timely fashion. Toward this end, ARS recently developed a Program Plan which outlines research possibilities for the next 20 to 50 years and a 6-Year Implementation Plan which identifies research areas for increased or decreased emphasis depending on the current research needs. ARS continues to seek ways to improve the efficient use of its facilities and will give increasing emphasis to the optimum use of facilities and resources as redirections prescribed in the 6-Year Implementation Plan are carried out.

INTENTIONAL BLANK

Priority setting is complex and dynamic. It is an interactive process among staff and line scientists and includes considerations of both the scientific community and research users. Decisions by the Secretary of Agriculture, Office of Management and Budget, and the Congress determine the ARS appropriation and can affect the allocation of funds to specific locations and areas of research. Within ARS, individual scientists, along with Area Directors and their staffs, significantly influence priorities based on their analyses of needs of equipment, facilities, and personnel for exploiting scientific opportunities. Outside of ARS, the Joint Council on Food and Agricultural Sciences, the Users Advisory Board, leaders of farm organizations, industrial groups, and professional societies can influence priorities. The USDA action and regulatory agencies that depend upon ARS for research--agencies such as the Animal and Plant Health Inspection Service, Soil Conservation Service, Food and Nutrition Service, Food Safety and Inspection Service, Agricultural Marketing Service, Federal Grain Inspection Service, and Foreign Agricultural Service--can also influence priorities. At times, the research needs of agencies such as the Environmental Protection Agency, Agency for International Development, Department of Defense, National Aeronautics and Space Administration, Extension Service, Forest Service, and Bureau of Land Management will enter the process. Analyses and projections by the Economic Research Service, other agencies, and organizations also will be considered.

For the setting of priorities, the Administrator's office relies on the Deputy Administrator and the National Program Staff (NPS) to plan, articulate, and evaluate national ARS programs. The NPS identifies research opportunities, research that is conducted by other organizations, and research needs that are expressed by user and advisory groups. The NPS develops recommendations for program redirections and budget requests. Those recommendations will be included in action memoranda, option papers, budget analyses, summaries of program reviews and evaluations, or other appropriate documents.

The main criteria for setting priorities and allocating resources are:

- Consistency with the objectives and goals of the Congress, the Department, and the Agency;

- Need for research to solve specific high priority national technical problems determined to be critical to the U.S. food and agriculture sector;

- Need for the research as expressed by ARS scientists, user groups, Federal agencies, and the general scientific community;

- Potential benefits expected from achieving the stated objectives;

- Research capabilities and capacity of the scientists, laboratory, or program;

- Probability of success;

- Amount and kind of research effort conducted by other research organizations.

Several factors may constrain the allocation of resources and kinds of research that ARS conducts and limit the flexibility in resource use. The following factors, which include major constraints, must be considered:

- Availability of scientific expertise. Successful research depends upon the training and experience of individual scientists and upon the teamwork within and among laboratories. For both individuals and research teams, many years are required to reach peak productivity.

- Limitations of geography, climate, and soil. For valid results, certain types of research, especially field research, must be conducted at problem sites and over extended periods.

- Nature of the problem. Much ARS research requires costly facilities and equipment that are problem-specific. Quarantine facilities and special equipment for work on recombinant DNA and foreign animal diseases are examples.

- Sequential nature of research. Often, one phase of research must be completed before the next phase can be started.

- Continuous adaptation of biological systems. Examples are the resistance of crop pests to chemical controls and the genetic improvement of crops that may introduce new vulnerabilities. Goals and priorities must be revised to meet new problems as they arise.

No totally objective formula is possible for setting priorities and allocating resources for research. Priority setting for research is the exercise of informed judgment. It is based on the criteria and constraints listed above; all the factors are important at some level of decision making. At the project level, scientific criteria and experience will predominate. At the national level, scientific criteria must be balanced with Federal policies and with the needs of action agencies and other users of research. It is the task of the Administrator, Deputy Administrator, and the NPS to achieve such a balance so that ARS may provide its scientists with the long-term stability and the firm commitments that are needed for creative research.

Part of achieving that balance and providing the environment for that creative research is assuring our scientists the use of the new "tools of the trade". Several new technologies are emerging from recent research in the biosciences, particularly the advances in molecular biology of the 1960's. ARS supports use and development of these new technologies to help find solutions for some of the most vexing and intractable problems facing U.S. agriculture.

Called biotechnology, this still-growing field now offers unprecedented opportunities to study and understand fundamental life processes precisely. Application of this knowledge can be used to solve problems, produce new products, and provide other economic and social benefits.

Many universities and industrial organizations treat biotechnology as a separate priority. However, ARS chooses to use biotechnology research throughout much of its total program as part of its arsenal of tools in fulfilling its specific missions and program goals. ARS does not concentrate its biotechnology research at specific centers, nor does it plan to do so. In fact, the 5 percent of the ARS fiscal year 1985 funding specifically devoted to biotechnology research is distributed among 200 scientists at 41 locations.

ARS' ongoing biotechnology research is directed toward the solution of high-priority agricultural problems of national scope. These include conserving and maintaining the quality of natural resources; reducing high costs of farm production, improving crop protection and production efficiency, and enhancing market value and quality of farm products; overcoming technical

barriers to marketing and export of agricultural products; and promoting human health and well-being through nutrition.

ARS formally reviews each research project at least once every three years. Program reviews are organized to determine whether current and projected research programs are consistent with the mission and established priorities of the agency. These reviews also assess progress and productivity of the scientists and determine the effectiveness of team research. Consideration is given to personnel assignments, allocation of resources and facilities, need for program changes, and ways to strengthen research. Review panels include research leaders and scientists from the laboratories under review and scientists from other Government agencies, the academic community, and industry.

Proposed new research projects compete for available program funds. Each proposed new project is reviewed by peer scientists from the agricultural science community to determine if it should be implemented.

One very effective method of reviewing research focuses on the scientist who carries it out. Application of the Research Grade-Evaluation Guide, grade levels for scientific positions are determined by committees (often referred to as peer panels) rather than by a single classification specialist--the usual practice in the Federal Government. Scientists prepare written material describing their research and an appropriate panel periodically reviews the position. Panels consist of a committee chairperson (usually a research manager), an executive secretary (a classification specialist), and five scientists.

ARS strongly supports the separate personnel system for scientific and technical personnel proposed by the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) that would change legal and regulatory barriers inhibiting our hiring and retaining scientific stars and superstars. In the meantime, we are exercising special care to be very selective in our initial selection procedures. This includes increasing use of search committees as appropriate to identify exceptionally promising new scientists to fill research vacancies at our major centers.

The use of postdoctoral fellows is an other excellent mechanism to bring new ideas, capabilities, and techniques to ARS research, and we are aggressively pursuing these advantages. The ARS research associateship program funded from the Administrator's office has grown from 25 positions in 1984 to 50 in 1985 and 100 will be funded in 1986. There are at present some 250 other postdoctoral scientists throughout ARS. In addition, ARS has a Fellowship Program which provides opportunities to research scientists and administrative personnel to participate in a one-year research or education program at an accredited domestic or foreign educational institution or research facility of their choice.

Those new ideas and capabilities continue to be necessary to ARS as we maintain our emphasis on mission-oriented, fundamental, long-range, high-risk research to solve specific problems. For several decades, the generation of fundamental agriculture knowledge, the "seed corn" of technology, has not kept pace with its exploitation into useful technology. That knowledge has been used to solve

relatively tractable problems at the expense of generating the new knowledge needed to solve resistant problems. Helping to fill the knowledge gap is clearly a Federal research responsibility, particularly in those rapidly advancing areas that offer potential for increasing agricultural productivity. In the judgment of ARS managers, mission-oriented, fundamental research should account for about 50 percent of the ARS program between 1984 and 1990. Historical and current data for the ARS investment in fundamental research and analysis of the changes in program emphasis projected for the six years indicate that the investment in fundamental research will not vary from 50 percent by more than plus or minus 10 percent. Whether we classify our research as fundamental or applied it is always problem-solving research.

Finally, Gentlemen, the mission, the planning, the priorities would mean little unless research results reached those who need and use them. We not only work very closely with other agencies of USDA but also with the private sector. Last year we had more than 60,000 contacts with business and industry to transfer our technology to the private sector. Many of these contacts were face-to-face discussions. The National Program Staff met with no fewer than 150 industry and commodity groups, and I was able to participate in 30 of these meetings. Such discussions and contacts help keep our 2,650 scientists operating in the "real world" of commerce and agriculture. In addition, the agency published its formal technology transfer program in 1984.

For the reference of the Task Force I have a few copies of the publications I've referred to--they may be of interest. This concludes my prepared statement, Mr. Chairman, I will be pleased to respond to any questions you may have.

Mr. FUQUA. Thank you very much, Dr. Kinney.
Dr. Jordan.

STATEMENT OF DR. JOHN PATRICK JORDAN, ADMINISTRATOR, COOPERATIVE STATE RESEARCH SERVICE, U.S. DEPARTMENT OF AGRICULTURE, WASHINGTON, DC

Dr. JORDAN. Mr. Chairman and members of the task force, thank you very much for the opportunity to come before you. I hope as a result of my presentation, the close working relationship between the Cooperative State Research Service, for which I am the Administrator, and the Agricultural Research Service, for which Dr. Kinney is the Administrator, will come through.

CSRS, as we are known, is the science and education agency through which Federal research funding and planning is accomplished on behalf of the U.S. Department of Agriculture in cooperation with 58 State and Territorial Agricultural Experiment Stations, 17 historically black land-grant institutions, including Tuskegee University, 28 schools of forestry, and 29 colleges of veterinary medicine. Most of these institutions are part of the land-grant university system.

When you total all the publicly supported agricultural research, including the research agencies of the U.S. Department of Agriculture, two-thirds of all the full-time equivalent scientists are found in the State Agricultural Experiment Station system. Because of the shared responsibilities between research and teaching and also between research and extension, the actual number of scientists involved is 12,500, who supervise 13,000 graduate students and 7,200 technicians. This, Mr. Chairman, provides a wide range of talent capable of addressing most kinds of problems faced by agriculture.

The funding of the total system of State Agricultural Experiment Stations and associated institutions is also relatively unique. The total amount of money available in that system last year totalled nearly $1.3 billion, but it comes from several sources—53 percent of it from State appropriations; 19 percent of it through the budget of the Cooperative State Research Service; another 10 percent from industrial organizations; 9 percent from other Federal agencies, particularly the National Science Foundation and the National Institutes of Health. Six percent of it comes from the sale of the residue of research, the sales of those products that are safe, and finally 3 percent from other USDA agencies, particularly the Agricultural Research Service and the Economic Research Service.

Mr. Chairman, I would like to specifically address the role of my agency in the science and engineering infrastructure and to outline our priority-setting process. The most significant thing I can say to you is that the program planning and priority setting is done in close cooperation with the State Agricultural Experiment Station system, and it is done on a systemwide basis, with CSRS providing a catalytic role that involves planning, priority-setting, and validation of the quality of research, and an evaluation of accomplishments.

The history of the current system dates back to the late 1960's, when the land-grant system began a 5-year cycle of planning, updated every 2 years. The system has moved recently to a more

structured strategic planning mode and in fact this year, Mr. Chairman, a national symposium followed by a workshop established the highest priorities on a national basis for the entire system.

Such strategic planning is translated into station-level planning and specific program-level planning for each fiscal year in the CSRS budget, and you'll see shortly from Dr. Huston how that is translated at the individual Station level. There are frequent tradeoffs that are seen at the Station level.

To give you an example, for nearly a dozen years I was director of the Colorado Agricultural Experiment Station, and that State ranks No. 1 in lands in feedlots. Nevertheless, that Station went out of the sheep research business. How was it able to do this? It was able to accomplish this by close coordination and cooperation with other agencies and States. To begin with, the USDA through the Agricultural Research Service has an excellent program in sheep research at Dubois, ID. Utah State University had a well coordinated and developed program at Logan, UT, and the University of Wyoming also has a significant research program in sheep. Our role at Colorado was to employ a very effective extension specialist to gather the information provided from these resources and package it in a form that could be used by the sheep producers of Colorado.

The tradeoff was that Colorado State University was able to focus its attention much more heavily on the reproduction of beef, a problem of highest priority in the State, and to put a lot more resources behind that. As a result of that effort, the institution provided leadership on a national basis, really, in superovulation, cloning of livestock, animal gene manipulation, and other technologies. Similar stories can be found and articulated for a number of other Stations as well.

At the heart of this effort is the assurance of quality of science, and that covers the entire span of research from the evaluation of a research concept to the accomplishment of research objectives. The basic mechanism through which assurance of quality of science is accomplished is the review by panels of scientists, highly competent in each scientific problem area. This is accomplished in about five ways: first of all, a system of Station-level peer reviews of individual project proposals; second, nationally organized panels of peers, particularly to address the Special Research Grants and always in the Competitive Research Grants program; third, active participation in regional research projects, which involves a coordinated effort of several States, along with appropriate Federal agencies, focusing on common problems; and a system of regular program reviews conducted at each research site with, again, a panel of peer experts; along with an annual review of each and every project at the Station level.

In the case of regional research, the project under development is critically reviewed by a research committee of the Regional Association of Experiment Station Directors. Following the recommendation of the regional research committee, the project is forwarded to CSRS only if it meets the approval criteria of the directors association. Upon receipt of a regional research project, CSRS arranges for its critical review by the committee of nine which has been es-

tablished by the Secretary of Agriculture for such purposes. The committee of nine, in the development of their review process, have at their disposal the entire scientific community as advisers and consultants. Thus, each project is provided ample opportunity for critical analysis and modification for possible improvement.

Mr. Chairman, you asked that I speak specifically about the mechanisms used to fund research programs within CSRS and the long-term trends in terms of program and mechanism. We use basically three mechanisms: Competitive Research Grants, Special Research Grants, and base program funding. If I may, I would like to discuss the size and scope, the assurance of quality, the strengths and weaknesses of each of these mechanisms. I hope this discussion will illustrate the distinct strengths of each mechanism and each approach. I also hope that I will now be able to show you that, when fitted together, these mechanisms do work well and each mechanism has their own niche to fill.

In fiscal year 1985 CSRS, through its Office of Grants and Program Systems, managed $54 million worth of Competitive Grants. These were in areas including biotechnology, plant sciences, animal sciences, pest sciences, human nutrition, and forestry. The Competitive Grants program is organized and managed in a manner quite analogous to the National Science Foundation. It is based on panels of peers that meet in Washington, DC, for the purpose of reviewing all proposals that are submitted in response to a published call for proposals, by scientists in universities, Federal laboratories, and in industry.

The average panel consists of about 14 scientists and generally reviews about 140 proposals, ranking them in the order of priority. The strength of this system is that it opens competition to the very best talent, regardless of whether it be public or private, Federal or State, industry or academic in its foundation. This program provides national focus and emphasizes innovative ideas and specific areas of research to be addressed. The major weaknesses of this system are the length of time and the cost involved in preparing proposals which generally are funded for relatively short periods of time—in CSRS, generally 2 years at a time. All decisions are made on a central basis nationally, and therefore it brings national focus as opposed to another mechanism which we'll talk about, which brings particularly State and local focus to it.

In fiscal year 1985, CSRS administered $32 million in the Special Research Grants category, which are targeted to specific problem areas and sometimes to specific locations. There were a total of 40 programs, each proposal of which was peer review. The strengths of this approach are that it brings definite focus to a problem area, gives it visibility, and provides funding for programs with a limited life span, generally in the range of 5 years, and it allows both the administration and the Congress to respond in a rather short timeframe to new needs. However, by identifying a specific site to conduct research, the quality of science may not be the highest and the research objective might be better served if a wider range of institutions and locations could be considered. Most of the Special Grants are in that category, where the site is not all that specified. Additionally, Special Research Grants invite a selection of specific projects by legislative action which, again, might not have the

same scientific credibility or standards as those required in the Competitive Research Grants program..

By far the largest mechanism that CSRS is involved in is the base or formula-funded program. In fiscal year 1985 it involved every aspect of agricultural research, including basic and applied research; plant, animal, and microbial oriented research; marketing and international trade; world communities and the people who live therein; as well as human nutrition and the use of agricultural products. The three major programs under this heading are the Hatch Program, which involves all the State Agricultural Experiment Stations, the colleges of home economics, the colleges of veterinary medicine, schools of forestry in the land-grant institutions, and amounts to $162.2 million. The Evans-Allen Program is for colleges eligible under the second Morrill Act and Tuskegee University, and amounts to $23.5 million. Finally, the McIntire-Stennis Program, which is available to 62 schools and departments of forestry, both in the land-grant universities and selected non-land-grant universities, and amounts to $13.1 million. On average, a dollar of this shared funded program—all of these three—leverages in more than $4 of funding from other sources.

The strong point in favor of this program is that it is conducted at the State level with State input and is overseen by the State legislature. Management is provided through the State land-grant university or other eligible institution. It inevitably involves and holds accountable the university president, the Experiment Station director, the dean and department heads, as well as individual scientists funded through this mechanism. It allows response to the highest priority needs of each State or territory. Its major weakness may be the question of whether the best talent to address a particular question is present in a given institution.

The basic mechanism for assuring the quality of research in this kind of program is the Station-level peer review system, and that in each and every case has been submitted to CSRS for approval and is on file in my office. CSRS, together with the land-grant university system, is currently examining the impact and quality of the review process itself. This is being done in full cooperation with the participating institutions.

Let me turn my attention, Mr. Chairman, if I might, to the issue of scientific expertise. CSRS, through the Office of Grants and Program Systems, houses the higher education program for the Department of Agriculture. This involves strengthening grants to the colleges of 1890 and Tuskegee University and the Morrill-Nelson Act, which is also targeted to the land-grant institutions. In addition, there is a training grant program supporting 300 predoctoral students.

These awards are made on the basis of national competition from proposals submitted by participating institutions. A panel of peers is used to select the winning institutions and proposals. This program, combined with the other sources of funding, supports masters level, Ph.D. level, and post-doctoral level students and provides the major mechanism through which the scientific talent to meet America's future needs in agricultural research, extension, and teaching. Let's remember, Mr. Chairman, that essentially all of the agricultural scientists of the United States, including virtually all

of those in the Federal research laboratories, are products of that educational system.

The major mechanisms for interfacing will be discussed at length tomorrow when Assistant Secretary Orville G. Bentley comes before this body. Let me share with you a flavor of what he will say, simply by indicating that the Joint Council on Food and Agricultural Sciences—a congressionally-mandated organization—is the place at which the Agricultural Research Services, the Economic Research Service, forestry research, the land-grant institutions, the non-land-grant institutions, teaching, research, and extension all meet on common ground for common planning and common execution of programs.

The payoff for this kind of effort is substantial for the United States. With respect to the Experiment Stations, we see with less than 20 percent of the funding coming from the Federal Government, the Nation shares the benefits for an overall agricultural research system involving all the State Agricultural Experiment Stations, and the system is well-coordinated with the Agricultural Research Services, the ERS, the U.S. Forest Service, and other relevant Federal research agencies. In fact, Mr. Chairman, there is daily contact between my office and the National Science Foundation and the National Institutes of Health, as to particular examples, as well as U.S. AID in the State Department.

Second, there are significant tradeoffs, as previously indicated, where one agency or Experiment Station may take an in-depth approach on a particular research question, sharing the results with other Stations and the Federal Government. Farmers and ranchers benefit from this in terms of cutting input costs, and the citizen benefits through the availability of high quality food, fiber, fuel, and forest products, but the baseline of this is, the major focus is in cutting input costs so that American agriculture can be competitive on a worldwide basis.

I would like to summarize by saying that CSRS uses three main forms of funding, all of which are built on the basis of review of the quality of science and thus the assurance of the quality of science by means of peer panels. Each funding mechanism has a different function. The base funding program provides a foundation upon which the other two, the Special and Competitive Grants programs, are built, and builds also a strong basis on which funding from other Federal agencies, the State agencies and the State legislatures, as well as industry, can be built within those institutions, those universities. Its priorities are set by the scientific community and carefully synchronized with those of the Joint Council on Food and Agricultural Sciences. The system fits neatly together, with complementarity in programs and in output to Federal laboratories. It is an ideal example of the New Federalism, where decentralized management and assurance of quality of science are at the heart of the system. No nation, sir—no nation—has ever built such a knowledge-based system with such high quality science at such a low relative Federal cost as we have. The Congress and the people of the United States, sir, are to be congratulated.

I would be pleased to answer questions.

[The prepared statement of Dr. Jordan follows:]

STATEMENT OF

DR. JOHN PATRICK JORDAN

ADMINISTRATOR

COOPERATIVE STATE RESEARCH SERVICE

U.S. DEPARTMENT OF AGRICULTURE

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

OCTOBER 3, 1985

COOPERATIVE STATE RESEARCH SERVICE

Mr. Chairman and Members of the Task Force: I am Dr. John Patrick Jordan, Administrator of the Cooperative State Research Service (CSRS). CSRS is the science and education agency through which federal research funding and planning are accomplished on behalf of the Department of Agriculture in cooperation with:

- 58 State and Territorial Agricultural Experiment Stations
- 17 Historically Black Land-Grant institutions, including Tuskegee University
- 28 Schools of Forestry, and
- 29 Colleges of Veterinary Medicine

Most of these institutions are a part of the Land-Grant university system. When you total all the publicly supported agricultural research, including all research agencies within the United States Department of Agriculture, two-thirds of all the full-time equivalent scientist years are found in the State Agricultural Experiment Station system. Because of shared responsibilities between research and teaching in the universities, the actual number of scientists involved is 12,500 who supervise 13,000 graduate students and 7,200 technicians. This provides a wide range of talent capable of addressing most kinds of problems faced by agriculture.

THE FUNDING LEVEL FOR THE TOTAL SYSTEM OF STATE AGRICULTURAL EXPERIMENT STATIONS AND ASSOCIATED INSTITUTIONS AMOUNTS TO NEARLY $1.3 BILLION PER YEAR. IT COMES FROM SEVERAL SOURCES. THE MOST RECENT DATA SHOW THE FOLLOWING SOURCES OF FUNDS:

o STATE APPROPRIATIONS	- 53%	o OTHER FEDERAL	- 9%
o CSRS APPROPRIATION	- 19%	o PRODUCT SALES	- 6%
o INDUSTRIAL ORGANIZATION	- 10%	o OTHER USDA	- 3%

EACH SOURCE OF FUNDING FILLS A SPECIFIC NICHE, BUT THE BASE FUNDING FOR THE ENTIRE SYSTEM COMES FROM THE COMBINATION OF STATE APPROPRIATED FUNDS AND FEDERAL FORMULA FUNDING THROUGH CSRS. PEAKS OF EXCELLENCE AND FOCUSED SCIENTIFIC EFFORT ARE PROVIDED THROUGH SOURCES OF FUNDING BEYOND THE BASE FUNDED PROGRAM.

INFRASTRUCTURE AND PRIORITY SETTING

IN ADDITION, MR. CHAIRMAN, I WOULD LIKE TO SPECIFICALLY ADDRESS THE ROLE OF MISSION AGENCIES IN THE SCIENCE AND ENGINEERING INFRASTRUCTURE AND TO OUTLINE OUR PRIORITY SETTING PROCESS. THE MOST SIGNIFICANT THING I CAN TELL YOU, IS THAT PROGRAM PLANNING AND PRIORITY SETTING IS DONE ON A SYSTEM-WIDE BASIS, WITH CSRS PROVIDING A CATALYTIC ROLE THAT INVOLVES PLANNING, PRIORITY SETTING, AND VALIDATION OF THE QUALITY OF RESEARCH, AND EVALUATION OF THE ACCOMPLISHMENTS.

THE HISTORY OF THE CURRENT SYSTEM DATES FROM THE LATE 1960'S, WHEN THE LAND-GRANT SYSTEM BEGAN PLANNING IN FIVE-YEAR CYCLES WITH UPDATES MADE EVERY TWO YEARS. THE SYSTEM HAS MOVED, MORE RECENTLY, TO A STRUCTURED STRATEGIC PLANNING MODE, AND IN FACT, THIS YEAR A NATIONAL SYMPOSIUM FOLLOWED BY A WORKSHOP ESTABLISHED THE HIGHEST PRIORITIES ON A NATIONAL BASIS FROM THE ENTIRE SYSTEM. SUCH STRATEGIC PLANNING IS TRANSLATED INTO STATION LEVEL PLANNING AND SPECIFIC PROGRAM LEVEL PLANNING FOR EACH FISCAL YEAR IN THE CSRS BUDGET. THERE ARE FREQUENT TRADE-OFFS AT THE STATION LEVEL.

TO GIVE YOU AN EXAMPLE, I WAS FOR NEARLY A DOZEN YEARS THE DIRECTOR OF THE COLORADO AGRICULTURAL EXPERIMENT STATION. THAT STATE RANKS AS NUMBER ONE IN THE NATION IN LAMBS IN FEED LOTS. NEVERTHELESS, OUR STATION WENT OUT OF THE SHEEP RESEARCH BUSINESS. HOW WERE WE ABLE TO DO THAT? WE WERE ABLE TO ACCOMPLISH IT BECAUSE THE USDA THROUGH ARS HAD AN EXCELLENT PROGRAM IN SHEEP RESEARCH AT DUBOIS, IDAHO; UTAH STATE UNIVERSITY HAD A WELL COORDINATED AND RELATED PROGRAM AT LOGAN, UTAH AND THE UNIVERSITY OF WYOMING ALSO HAD SOME RESEARCH IN SHEEP. OUR ROLE IN COLORADO, WAS TO HAVE A VERY COMPETENT EXTENSION SPECIALIST GATHER THE INFORMATION PROVIDED FROM THESE SOURCES AND PACKAGE IT FOR USE BY THE SHEEP PRODUCERS OF COLORADO. THE TRADE-OFF WAS THAT COLORADO STATE UNIVERSITY WAS ABLE TO FOCUS ITS ATTENTION MUCH MORE HEAVILY ON REPRODUCTION IN BEEF, A PROBLEM OF HIGHEST PRIORITY TO THE STATE. AS A RESULT OF THAT EFFORT, CSU PROVIDED LEADERSHIP IN SUPEROVULATION, CLONING OF LIVESTOCK, AND ANIMAL GENE MANIPULATION. SIMILAR STORIES ARE FOUND IN A NUMBER OF OTHER STATIONS.

ASSURANCE OF THE QUALITY OF SCIENCE COVERS THE ENTIRE SPAN OF RESEARCH FROM THE EVALUATION OF A RESEARCH CONCEPT TO THE ACCOMPLISHMENT OF THE RESEARCH OBJECTIVES. THE BASIC MECHANISM THROUGH WHICH THE ASSURANCE OF QUALITY OF SCIENCE IS ACCOMPLISHED IS THE REVIEW BY PANELS OF SCIENTISTS HIGHLY COMPETENT IN EACH SCIENTIFIC PROBLEM AREA. THIS IS ACCOMPLISHED THROUGH: (A) A SYSTEM OF STATION LEVEL PEER REVIEWS OF INDIVIDUAL PROJECT PROPOSALS; (B) NATIONALLY ORGANIZED PANELS OF PEERS, PARTICULARLY IN THE SPECIAL GRANTS AND ALWAYS IN THE COMPETITIVE GRANTS PROGRAM; (C) ACTIVE PARTICIPATION IN REGIONAL RESEARCH PROJECTS WHICH INVOLVE A COORDINATED EFFORT OF SEVERAL STATES, ALONG WITH APPROPRIATE FEDERAL AGENCIES FOCUSED ON A COMMON PROBLEM; AND (D) A SYSTEM OF REGULAR PROGRAM REVIEWS CONDUCTED AT EACH RESEARCH SITE WITH, AGAIN, A PANEL OF PEER EXPERTS; ALONG WITH (E) AN ANNUAL REVIEW OF EACH AND EVERY PROJECT AT THE STATION LEVEL.

IN THE CASE OF REGIONAL RESEARCH THE PROJECT UNDER DEVELOPMENT IS CRITICALLY REVIEWED BY A RESEARCH COMMITTEE OF THE REGIONAL ASSOCIATION OF EXPERIMENT STATION DIRECTORS. FOLLOWING RECOMMENDATION OF THE REGIONAL RESEARCH COMMITTEE, THE PROJECT IS FORWARDED TO CSRS ONLY IF IT MEETS THE APPROVAL CRITERIA OF THE DIRECTORS ASSOCIATION. UPON RECEIPT OF A REGIONAL RESEARCH PROJECT, CSRS ARRANGES FOR ITS CRITICAL REVIEW BY THE COMMITTEE OF NINE WHICH HAS BEEN ESTABLISHED BY THE SECRETARY OF AGRICULTURE FOR SUCH PURPOSES. THE COMMITTEE OF NINE, IN THE DEVELOPMENT OF THEIR REVIEW PROCESS, HAVE AT THEIR DISPOSAL THE ENTIRE SCIENTIFIC COMMUNITY AS ADVISORS AND CONSULTANTS. THUS, EACH PROJECT IS PROVIDED AMPLE OPPORTUNITY FOR CRITICAL ANALYSIS, AND MODIFICATION FOR POSSIBLE IMPROVEMENT.

57-279 O - 87 - 8

Mr. Chairman, you asked that I speak specifically about the mechanisms used to fund research programs within CSRS and the long-term trends in terms of program and mechanism. We use basically three mechanisms: Competitive Research Grants, Special Research Grants, and Base Program Funding. If I may, I would like to discuss the size and scope, the assurance of quality, the strengths and weaknesses of each of these mechanisms. I hope this discussion will illustrate the distinct strengths of each mechanism and each approach I also hope to show that those mechanisms allows the weaknesses of any other specific funding mechanism to be minimized.

COMPETITIVE GRANTS

In FY 1985, CSRS through its Office of Grants and Program Systems managed $54 million worth of competitive grants. In the following program areas:

o Biotechnology	$20,000,000
o Plant Science	$16,500,000
o Animal Science	$ 4,500,000
o Pest Science	$ 3,000,000
o Human Nutrition	$ 2,000,000
o Forestry	$ 8,000,000

The competitive grants program is organized and managed in a manner analogous to the National Science Foundation. It is based upon panels of peers that meet in Washington, D.C. for the purpose of reviewing all proposals, submitted in response to a published call for proposals, by scientists in universities, Federal laboratories, and in industry. The average panel consists of about 14 scientists and generally reviews 140 proposals, ranking them in order of

PRIORITY. THE STRENGTH OF THIS SYSTEM IS THAT IT OPENS COMPETITION TO THE VERY BEST TALENT REGARDLESS OF WHETHER IT IS PUBLIC OR PRIVATE, FEDERAL OR STATE, INDUSTRY OR ACADEMIC. THIS PROGRAM PROVIDES NATIONAL FOCUS AND EMPHASIZES INNOVATIVE IDEAS IN THE SPECIFIC AREAS OF RESEARCH TO BE ADDRESSED. THE MAJOR WEAKNESSES OF THIS SYSTEM ARE THE LENGTH OF TIME AND COSTS INVOLVED IN PREPARING PROPOSALS WHICH GENERALLY ARE FUNDED FOR SHORT-TERMS (FOR CSRS, GENERALLY TWO YEARS AT A TIME). ALL DECISIONS ARE MADE ON A CENTRALIZED AGENCY BASIS. HOWEVER, THE STRENGTHS OF THE PROGRAM FAR OUTWEIGHS THE WEAKNESSES.

SPECIAL GRANTS

IN FY 1985, CSRS ADMINISTERED $32 MILLION IN SPECIAL RESEARCH GRANTS WHICH ARE TARGETED TO SPECIFIC PROBLEM AREAS AND SOMETIMES TO SPECIFIC LOCATIONS. THERE WERE A TOTAL OF 40 PROGRAMS, EACH PROPOSAL OF WHICH WAS PEER REVIEWED. IF THE PROJECT IS STATE SPECIFIC, IT WAS PEER REVIEWED WITHIN THE APPROVED DECENTRALIZED PEER PANEL SYSTEM OF THE UNIVERSITY INVOLVED. FOR PROGRAMS THAT CROSS STATE BOUNDARIES OR INVOLVE SEVERAL INSTITUTIONS, CSRS ORGANIZED A NATIONAL LEVEL PEER REVIEW SYSTEM, BEING CAREFUL TO SELECT ONLY THE BEST SCIENTISTS IN THE FIELDS TO BE REVIEWED. THE STRENGTHS OF THIS APPROACH ARE THAT IT BRINGS DEFINITE FOCUS TO A PROBLEM AREA AND GIVES IT VISIBILITY, PROVIDES FUNDING FOR PROGRAMS WITH A LIMITED LIFE SPAN (GENERALLY IN THE RANGE OF FIVE YEARS) AND ALLOWS BOTH THE ADMINISTRATION AND THE CONGRESS TO RESPOND IN A RATHER SHORT TIME FRAME TO NEW NEEDS. HOWEVER, BY IDENTIFYING A SPECIFIC SITE TO CONDUCT RESEARCH, THE QUALITY OF SCIENCE MAY NOT BE THE HIGHEST AND THE RESEARCH OBJECTIVE MIGHT BE BETTER SERVED IF A WIDER RANGE OF INSTITUTIONS AND LOCATIONS COULD BE CONSIDERED. ADDITIONALLY, THE SPECIAL RESEARCH GRANTS PROGRAM INVITES A SELECTION OF SPECIFIC PROJECTS BY LEGISLATIVE ACTION, WHICH MIGHT NOT HAVE THE SAME SCIENTIFIC CREDIBILITY OR STANDARDS AS THOSE REQUIRED IN THE COMPETITIVE RESEARCH GRANTS PROGRAM.

BASE FUNDING

THE BASE OR FORMULA FUNDED PROGRAM OF CSRS IN FY 1985 INVOLVED EVERY ASPECT OF AGRICULTURAL RESEARCH, INCLUDING BASIC AND APPLIED RESEARCH; PLANT, ANIMAL AND MICROBIAL ORIENTED RESEARCH; MARKETING AND INTERNATIONAL TRADE; RURAL COMMUNITIES AND THE PEOPLE WHO LIVE THEREIN; AS WELL AS HUMAN NUTRITION AND THE USE OF AGRICULTURAL PRODUCTS. THE THREE MAJOR PROGRAMS UNDER THIS HEADING ARE: •HATCH - STATE AGRICULTURAL EXPERIMENT STATIONS, COLLEGES OF HOME ECONOMICS, COLLEGES OF VETERINARY MEDICINE, SCHOOLS OF FORESTRY IN LAND-GRANT UNIVERSITIES ($162.2M); •EVANS-ALLEN - COLLEGES ELIGIBLE UNDER THE SECOND MORRILL ACT AND TUSKEGEE UNIVERSITY ($23.5M); •MCINTIRE-STENNIS - 62 SCHOOLS AND DEPARTMENTS OF FORESTRY, BOTH IN LAND-GRANT UNIVERSITIES AND NON-LAND-GRANT UNIVERSITIES ($13.1M). ON AVERAGE, A DOLLAR IN THIS SHARED FUNDED PROGRAM LEVERAGES IN MORE THAN $4 OF FUNDING FROM OTHER SOURCES.

A STRONG POINT IN FAVOR OF THIS PROGRAM IS THAT IT IS CONDUCTED AT THE STATE LEVEL WITH STATE INPUT AND IS OVERSEEN BY THE STATE LEGISLATURE. MANAGEMENT IS PROVIDED THROUGH THE STATE LAND-GRANT UNIVERSITY OR OTHER ELIGIBLE INSTITUTION. IT INEVITABLY INVOLVES AND HOLDS ACCOUNTABLE THE UNIVERSITY PRESIDENT, THE EXPERIMENT STATION DIRECTOR, THE DEAN AND DEPARTMENT HEADS, AS WELL AS THE INDIVIDUAL SCIENTISTS FUNDED THROUGH THIS MECHANISM. IT ALLOWS RESPONSE TO THE HIGHEST PRIORITY NEEDS IN EACH STATE AND TERRITORY. ITS MAJOR WEAKNESS MAY BE THE QUESTION OF WHETHER THE BEST TALENT TO ADDRESS A PARTICULAR QUESTION IS PRESENT IN A GIVEN INSTITUTION.

THE BASIC MECHANISM FOR ASSURING THE QUALITY OF RESEARCH IS A STATION LEVEL PEER REVIEW SYSTEM THAT HAS BEEN APPROVED BY THE ADMINISTRATOR OF CSRS AND IS ON FILE IN CSRS. ONLY THREE OF THE PARTNER INSTITUTIONS HAVE FAILED TO PROVIDE AN APPROVED STATION LEVEL PEER REVIEW SYSTEM, AND OF THOSE, ONE HAS SUBMITTED A PLAN, ONE IS DEVELOPING A PLAN, AND THE THIRD HAS THE ISSUE UNDER RECONSIDERATION. IN THE CASE OF THOSE THREE UNIVERSITIES, THE SCIENTIST OF CSRS ASSURE THAT A PEER REVIEW IS CONDUCTED ON EACH PROJECT. OTHERWISE, THE PEER REVIEW PROCESS IS CONDUCTED AT THE LOCAL LEVEL. CSRS IS CURRENTLY EXAMINING THE IMPACT AND QUALITY OF THE REVIEW PROCESS ITSELF, AND THIS IS BEING DONE IN COOPERATION WITH THE LAND-GRANT UNIVERSITY SYSTEM.

IN ADDITION, CSRS, IN COOPERATION WITH THE STATE AGRICULTURAL EXPERIMENT STATION SYSTEM SPONSORS 240 REGIONAL RESEARCH PROJECTS, EACH OF WHICH GENERALLY INVOLVES A HALF-DOZEN OR SO STATES AND APPROPRIATE FEDERAL LABORATORIES TO ADDRESS SPECIFIC PROBLEMS OF RESEARCH COMMON TO MORE THAN ONE STATE. THESE PROJECTS ARE THE RESULT OF REGIONAL LEVEL PLANNING, CARRIED OUT IN CONCEPT WITH APPROPRIATE FEDERAL LABORATORIES AND CSRS BY THE FOUR STATE AGRICULTURAL EXPERIMENT STATION REGIONAL RESEARCH ORGANIZATIONS.

SCIENTIFIC EXPERTISE

LET ME TURN MY ATTENTION TO THE ISSUE OF SCIENTIFIC EXPERTISE. CSRS, THROUGH THE OFFICE OF GRANTS AND PROGRAM SYSTEMS, HOUSES THE HIGHER EDUCATION PROGRAM FOR THE DEPARTMENT OF AGRICULTURE. THIS INVOLVES STRENGTHENING GRANTS TO THE COLLEGES OF 1890 AND TUSKEGEE UNIVERSITY AND THE MORRILL-NELSON ACT, WHICH IS

ALSO TARGETED TO THE LAND-GRANT INSTITUTIONS. IN ADDITION, THERE IS A TRAINING GRANT PROGRAM SUPPORTING 300 PRE-DOCTORAL STUDENTS. THESE AWARDS ARE MADE ON THE BASIS OF NATIONAL COMPETITION FROM PROPOSALS SUBMITTED BY PARTICIPATING INSTITUTIONS. A PANEL OF PEERS IS USED TO SELECT THE WINNING INSTITUTIONS AND PROPOSALS. THIS PROGRAM, COMBINED WITH THE OTHER SOURCES OF FUNDING SUPPORTING MASTERS LEVEL, THE PH.D. LEVEL AND THE POST-DOCTORAL LEVEL STUDENTS, PROVIDES THE MAJOR MECHANISM THROUGH WHICH SCIENTIFIC TALENT TO MEET AMERICA'S FUTURE NEEDS IN AGRICULTURE RESEARCH, EXTENSION AND TEACHING ARE TO BE MET. IT ALSO PROVIDES FUNDING FOR STUDENTS WHO ARE IN PROGRAM AREAS NOT SUPPPORTED BY PROJECT FUNDING YET WHO ARE IN DISCIPLINES NEEDED BY AGRICULTURE. INCLUDED IN THIS PROGRAM IS AN EXTENSIVE ANALYSIS PROJECT, DOCUMENTING THE NEED FOR HIGHLY TRAINED AGRICULTURAL SCIENTISTS. THE RESULTS OF THE PROJECT WERE FIRST PUBLISHED IN 1980 AND A REVISION OF THIS STUDY WILL BE AVAILABLE BY THE END OF 1985. LET US REMEMBER THAT ESSENTIALLY ALL OF THE AGRICULTURAL SCIENTISTS OF THE UNITED STATES, INCLUDING VIRTUALLY ALL OF THOSE IN FEDERAL RESEARCH LABORATORIES, ARE PRODUCTS OF THIS EDUCATIONAL SYSTEM.

THE MAJOR MECHANISMS OF INTERFACING WILL BE DISCUSSED AT LENGTH TOMORROW WHEN ASSISTANT SECRETARY ORVILLE G. BENTLEY COMES BEFORE THIS BODY. LET ME SHARE WITH YOU THE FLAVOR OF WHAT HE WILL SAY BY INDICATING THAT THE JOINT COUNCIL ON FOOD AND AGRICULTURAL SCIENCES, A CONGRESSIONALLY MANDATED ORGANIZATION, IS THE ORGANIZATION IN WHICH ALL FEDERAL AGENCIES INVOLVED IN AGRICULTURAL RESEARCH, EXTENSION AND TEACHING MEET THEIR COUNTERPARTS FROM THE STATES, AND FROM INDUSTRY TO INSURE THAT THIS NATION HAS A COORDINATED OVERALL PLAN AND RESEARCH THRUST IN THESE IMPORTANT AREAS. IT IS THE MECHANISM THROUGH WHICH THE

EXPERIMENT STATION SYSTEM PLANS ARE FITTED TOGETHER WITH PLANS FOR RESEARCH TO BE ACCOMPLISHED BY ARS, ERS AND USFS AS WELL AS OUTREACH PROGRAMS OF THE EXTENSION SERVICE. COORDINATION WITH ACADEMIC PROGRAMS IS ALSO EFFECTED THROUGH THE JOINT COUNCIL. THUS, JOINT COUNCIL PRIORITIES FOR ANY GIVEN YEAR ARE INDEED NATIONAL PRIORITIES WITH SPECIFIC EXPRESSION IN THE STATE AGRICULTURAL EXPERIMENT STATION SYSTEM PLANS AS WELL AS THOSE OF ALL THE ORGANIZATION ALREADY IDENTIFIED.

PAYOFF

THE PAYOFF FOR THE UNITED STATES IS SUBSTANTIAL. WITH LESS THAN 20% FUNDING FROM THE FEDERAL GOVERNMENT, THE NATION SHARES THE BENEFITS FROM THE OVERALL AGRICULTURAL RESEARCH SYSTEM, INVOLVING ALL OF THE STATE AGRICULTURAL EXPERIMENT STATIONS [AND OTHER RELATED, RESEARCH-PERFORMING INSTITUTIONS.] THE SYSTEM IS WELL COORDINATED WITH THE AGRICULTURAL RESEARCH SERVICE, THE ECONOMIC RESEARCH SERVICE, THE U. S. FOREST SERVICE AND OTHER RELEVANT FEDERAL RESEARCH AGENCIES. SECONDLY, THERE ARE SIGNIFICANT TRADE-OFFS AS PREVIOUSLY INDICATED, WHERE ONE AGENCY OR EXPERIMENT STATION MAY TAKE AN INDEPTH APPROACH ON A PARTICULAR RESEARCH QUESTION, SHARING THE RESULTS WITH OTHER STATIONS AND THE FEDERAL GOVERNMENT. THE FARMER AND RANCHER BENEFITS FROM THIS IN TERMS OF CUTTING INPUT COST AND THE CITIZEN BENEFITS THROUGH THE AVAILABILITY OF HIGH QUALITY FOOD, FIBER, FUEL AND FOREST PRODUCTS. THE MAJOR FOCUS OF RESEARCH IS IN CUTTING THE INPUT COST, SO THAT AMERICAN AGRICULTURE CAN BE COMPETITIVE WORLD-WIDE.

SUMMARY

LET ME SUMMARIZE BY SAYING THAT CSRS USES THREE MAIN FORMS OF FUNDING, ALL OF WHICH ARE BUILT ON THE BASIS OF REVIEW OF THE QUALITY OF SCIENCE, AND THUS, THE ASSURANCE OF THE QUALITY OF SCIENCE BY MEANS OF PANELS OF PEERS. EACH FUNDING MECHANISM HAS A DIFFERENT FUNCTION. THE BASE FUNDING PROGRAM PROVIDES THE FOUNDATION UPON WHICH THE SPECIAL AND COMPETITIVE GRANTS PROGRAMS OF THE USDA, AS WELL AS THOSE OF OTHER FEDERAL AGENCIES, STATE AGENCIES, AND THE STATE LEGISLATURES, AS WELL AS INDUSTRY CAN BE BUILT. IT'S PRIORITIES ARE SET BY THE SCIENTIFIC COMMUNITY AND ARE CAREFULLY SYNCHRONIZED WITH THOSE OF THE JOINT COUNCIL ON FOOD AND AGRICULTURAL SCIENCES. THE SYSTEM FITS NEATLY TOGETHER, WITH COMPLEMENTARITY IN PROGRAMS AND IN OUTPUT TO FEDERAL LABORATORIES. IT IS AN IDEAL EXAMPLE OF THE NEW FEDERALISM WHERE DECENTRALIZED MANAGEMENT AND ASSURANCE OF QUALITY OF SCIENCE ARE AT THE HEART OF THE SYSTEM. NO NATION HAS EVER BUILT SUCH A KNOWLEDGE-BASED SYSTEM WITH SUCH HIGH QUALITY SCIENCE, AT SUCH LOW RELATIVE FEDERAL COST. THE CONGRESS AND THE PEOPLE OF THE UNITED STATES ARE TO BE CONGRATULATED.

MR. CHAIRMAN, I WOULD BE PLEASED TO ANSWER ANY QUESTIONS.

Mr. FUQUA. Thank you very much, Dr. Jordan.
Dr. Huston.
[A biographical sketch of Dr. Huston follows:]

DR. KEITH HUSTON

Keith Huston serves as Director-at-Large for the North Central Regional Association of State Agricultural Experiment Station Directors. Educated at Wisconsin, Dr. Huston was later employed as a professor of dairy science, specializing in dairy cattle genetics, at Virginia Polytechnic Institute and State University, Kansas State University, and the University of Minnesota. Commencing his administrative career in 1969, Dr. Huston has served as assistant and associate director of the Kansas Agricultural Experiment Station and as director of the Minnesota Agricultural Experiment Station.

Dr. Huston currently is Co-Chairman of the National Agricultural Research Committee (NARC) of the Joint Council on Food and Agricultural Sciences (JCFAS). He has served as Chairman of the Experiment Station Committee on Organization and Policy (ESCOP); Chairman of the Committee of Nine; Co-Chairman of the International Science and Education Council (ISEC) Research Committee, and President of the Agriculture Research Institute, Washington, D.C. His service on national committees and task forces includes: World Food and Nutrition Study, National Academy of Sciences-National Research Council; Panel on Agricultural Research, Office of Technology Assessment (OTA); Ad Hoc Joint Committee on Country Programs, Title XII Legislation, Agency for International Development; Commission on Undergraduate Education in Agriculture and Natural Resources, National Academy of Sciences-National Research Council.

STATEMENT OF DR. KEITH HUSTON, COCHAIRMAN, NATIONAL AGRICULTURAL RESEARCH COMMITTEE, AND DIRECTOR-AT-LARGE, NORTH CENTRAL STATE AGRICULTURAL EXPERIMENT STATION DIRECTORS, WOOSTER, OH

Dr. HUSTON. Mr. Chairman and members of the committee, what I should like to do this morning is to focus principally on the differences in research as it is conducted in agriculture and the Agricultural Experiment Stations, so that you can see the contrast between it and other types of research organizations that you are examining.

I suspect you may have some curiosity as to what a director-at-large is. I am employed by 12 State Experiment Stations, the universities, land-grant universities from Ohio west to Kansas and everything north of there, and there are three others like me in the country. We are part of the glue that holds the State system and makes it a regional and national system, so that's about what I do. I float around the countryside.

The Experiment Stations are a unique organization and have unique funding mechanisms. They differ from the Federal agencies and they differ also from the university groups that you know in typical form. We are proud of the fact that we are a time-tested system. We have been in existence 100 years. We have been to the Hill 100 years and we have been to the State legislatures for as long as there has been a State legislature and a State Experiment Station, and we continue to survive in a relatively competitive, complex world.

Our system has been examined in great detail by countless numbers of scientists and studies, and we keep coming out with a very high return on costs, a high return on investments, and a suggestion that there is sizeable underinvestment. If I may suggest, I

would like to see some of the other sciences subjected to similar examination to see where they come out.

We are a part of the university community. We meet all of the standards of the university community and, despite the fact that Federal grants are extremely important to university professors in terms of their careers, the ultimate decision about whether a man holds a job in a university or not is made by university standards, and those are the standards to which we must submit.

The State Agricultural Experiment Station system is a part of a Federal-State partnership. That was identified by the Congress, just very recently reaffirmed, and in that partnership the State Experiment Stations receive about two-thirds of their funds from the State and about one-third to a quarter from the Federal Government. Now that contrasts with other sciences in the university because other sciences receive about a third to a quarter from the State and two-thirds to three-quarters from the Federal Government, so it's an exact switch between the two. In fact, if you want to do some counting in terms of resources, you find that the agricultural sciences receive more non-Federal support for research than any other group of sciences, including the medical sciences, which is hard to believe, but that gives you some notion of the concern that is spread across the country in our sciences.

Dr. Jordan has talked about our relations in terms of our size. We are the biggest research system in the country and we do a large share of the research, a broad-based research that covers everything from agriculture to forestry to home economics to veterinary medicine to rural development, rural and home community affairs, environmental affairs, and the gamut.

Now what I would like to do very quickly here is to give you a quick feel for the Experiment Stations. I know you have all been there but you may not have recognized it when you got there. The problem is that most of the Experiment Stations are on a land-grant university campus, and most of those campuses are huge places. Aside from the football stadium and sometimes the basketball stadium, it is kind of difficult to remember which building is which.

It turns out that in the State were I live, Ohio, the Station was separated from Ohio State University many, many years ago, and it's off in a little rural city called Wooster. In that same city there is a little land-grant college called the College of Wooster, an excellent, very excellent liberal arts college, has about 1,500 to 1,800 students. It turns out that if you compare the buildings on the College of Wooster with the buildings on the Ohio Experiment Station, it's about the same size, so you get a feel for how big it is in terms of physical plant.

Now the system that is there is characteristically organized like this: There is usually a headquarters unit. It is usually on the land-grant university campus. Now it turns out in California that they've got three places where they put these major centers, because the State is a very large and complex one, but in most States there is a headquarters unit and then there are branch locations strategically scattered across the State. They range all the way from as few as three or four in some of our Northeastern States to as many as 30 or 40 or 50 locations in other States.

The Experiment Stations characteristically are large farms. In my own region—and I know the land holdings better in my own region than in others—in one of my States the station handles something over 30,000 acres. It may have the largest beef herd, the largest dairy herd, the largest swine herd, the largest poultry flock. It may have the largest acreage of corn in the State, so they are heavily involved in production agriculture.

Now among the stations, the California Station is the largest. It is larger than the next two, which are Florida and Texas. It has one of the most diverse agricultures of any of the Stations and in many ways some of the most interesting challenges in the system.

The Stations are part of a land-grant university. The Stations are a part of this university research community, these research universities that people keep talking about. In fact, something like 30 to 35 of our States are part of that research system. Some of them are in smaller institutions but, by and large, they are part of that research community and they meet those same standards.

The partnership, as Dr. Jordan explained, came out of the Congress in the Hatch Act of 1887. We get Federal funds that come to us on a formula basis, about 15 percent of our dollars. Now in California and Florida the dollars are like 3 and 4 percent of the total resources that go into those stations there. In this formula funding, every State participates. You have low administrative costs and the decisionmaking with regard to research is made on the scene, where the action is.

Now the Hatch Act required matching. In other words, the States have to match what the Federal Government puts in and, as Dr. Jordan indicated, you get an awful lot of leverage for that 12 or 13 percent that you put into the States. The attachment to the land-grant university means that there is efficiency of resource utilization because we're tied into the colleges and we're tied into the Cooperative Extension Service.

Now it's significant to recognize that in terms of training the next generation of scientists, that the Experiment Stations are the primary contributor. We kick in 75 percent of all of the graduate assistantships that enable young men and women to pursue graduate work in agriculture. We are the "biggies" in terms of supporting that. We share our facilities, we share our equipment, and we share faculty with the collegiate and sometimes the Extension people.

We have, in terms of an organizational structure, a kind of a hybrid between a Federal line agency in which there is a strong hierarchy, and the university system in which we have a collegial system, in which we get together as a group and try to reach some sort of a decision as a group of equals, so we do have centralized authority. We have a centralized budget. We have a centralized direction to planning, and we have dual responsibility to both Federal and State Government. In fact, I suspect that if you were to look at the Experiment Station in terms of complex political arrangements, it probably is one of the most complex beasts that you could study because it must report both to State and Federal and then, in addition, has grant sources from a whole variety of groups, commodity groups, trade associations, and so on.

Now in that Hatch mechanism, in the Federal mechanism that gave birth to the stations and has helped sustain the Stations, there is a fraction of those resources, about a quarter, called a regional research fund. That regional research fund makes it possible for our States to work together, among themselves and with the Federal agencies—ARS, Forest Service, ERS, and any other agency that wants to participate—in such a way that we can address problems of any magnitude. They can be so little as a county area in a State or so big as national, and we can address them and we can address them in a voluntary way, as we see it appropriate.

Our support, if you look at it in the university community, is direct. We have a mission, and the people who fund us know what we are about. The rest of the university science community by and large receives most of their non-Federal funding as indirect support associated with the graduate programs, associated with research, faculty development activities.

I have been asked to mention briefly some of the trends and policy needs. One that we have lived with ever since I have been in the business is that the user needs seem almost inexhaustible. You keep working away, and they keep coming back, and you get one answer, and they want another answer. So in this perspective our resources have always been limited and we could always use more money. There are some changes, though, in these user needs, in that the problems that they throw at us are more complex than they have been, and you would expect this because you get the simple ones solved and you've got the complex ones left.

The other thing that is interesting is that the solutions as they emerge are adopted much more quickly than they used to be. We used to have a kind of a spare shelf back here where you could put the discoveries, and maybe 5 or 8 years down the road that thing would get used. Those things are picked up immediately. In fact, we have a situation in which many of our best farmers call the Experiment Station scientist—they know him by name—in their particular area and say, "What should I do? What is this situation?"

Now the sad part of all of this is that the scientists are still human beings. They can only do so much, and their minds will only comprehend so much and as the knowledge, the information sources, increase, then we have a tendency on the part of the scientist to specialize and specialize, which means then if you have a problem of a given size that it is going to take more and more scientists to work on that specific problem, so we have a concern now about expanding the number of individuals, the teams, to solve those problems. Now what it really means is that if your resources are stable, level, as ours have been, that you have to pick and choose—despite the pressures—you have to pick and choose more carefully with regard to those problems that you tackle and attempt to solve.

We have considerable flexibility in the Experiment Stations because of the fact that our Federal funds and our State funds come as a lump to the Station—not to an individual scientist, not to a department, not to a college, not to a university, but to a single Station—that those come in lump sum and the allocations then can be made as seems appropriate at the director's level, at the next level of allocation to the science level.

The second feature of these appropriations is that, after 100 years of permanence, they begin to seem permanent and you think you can count on them, and that is very important in developing science programs because you must have some source of sustained funding in order to have the scientists, in order to attack long-term problems, and in order to solve them. We believe that these appropriations, the Federal and State, are very, very significant in this thing.

Now one of the things that is worrying us in terms of the future is, there are new opportunities that keep emerging—biotechnology, genetic engineering, DNA manipulation, computer technology, sensors, and automated research systems. Automated research systems—it is almost unbelievable because you can go in to the lab people, where you used to have to buy them a little bit of glassware and little thing to hang the glassware on and lots of people to do these complex analyses, now you put it in a gadget and it runs out the answer almost as fast as you can feed the stuff in.

On the plant side, in our plant breeding work, we used to hire a bunch of high school and college kids to come in and take each wheat head at harvest time and put them in an envelope, and harvest it that way in order to have the experimental seed. Now we've got machines that are going to do this thing, and we can do three and four and five times as much as we used to do. These new opportunities are extremely important. We don't know how rapidly we can move resources in to take advantage of them.

I would like to finish up by speaking briefly about the roles of public and private. We have always, on the State side, we have always been closely tied to our producers, to our processors, to our marketers, to our distributors, and we work back and forth, trying to respond to the issues as they see them. The separation that seems to be so characteristic on the Washington scene, if I may say so, the separation between Government and industry seems to us at the State level to be a forced relationship—that there may be some real, distinct advantages from a closer relationship and a closer understanding of the two.

Thank you.

[The prepared statement of Dr. Huston follows:]

Statement of

Dr. Keith Huston

Director-at-Large

North Central Regional Association of State Agricultural Experiment Station Directors

Before the

Committee on Science and Technology

U. S. House of Representatives

October 3, 1985

I am Keith Huston, Director-at-Large for the North Central Regional Association of State Agricultural Experiment Station Directors. I report today on behalf of the Experiment Station Committee on Organization and Policy (ESCOP), the national executive committee for all State Experiment Stations.

RESEARCH AT THE STATE AGRICULTURAL EXPERIMENT STATIONS

INTRODUCTION: THE SAES, AN UNIQUE ORGANIZATIONAL MODEL

The State Agricultural Experiment Stations (SAES), individually and collectively, are organized, managed, and funded in a distinctively different fashion than other scientific research organizations funded by the federal government. Similarly, fields of science in agriculture are organized, funded, and sustained in a manner different from most other science fields. Despite these differences, the SAES, with one exception, are all parts of state land-grant university systems and thus a part of the larger university science community. Most land-grant universities are major research universities and thus a part of the research university community so dependent on the federal funds for continued existence and well-being of their research programs. Examination of some distinctive features of the SAES and the fields of science in agriculture may provide insights into options for funding and managing science different from those now common in most federal agencies.

Although the organization of agricultural research and sciences seems perfectly natural to agricultural scientists and users of agricultural science, it often has worried other scientists. Indeed, some have, on occasion, been critical. In that connection, it is important to remember that the organization, costs and benefits of agricultural research and thus of its sciences, have been studied exhaustively. The evidence indicates that the agricultural research model is and has been an highly effective one, so effective indeed that other fields of science, should they ever subject themselves to such study, might be hard pressed to match that record.

NATIONAL ORGANIZATION OF AGRICULTURAL RESEARCH: A FEDERAL-STATE PARTNERSHIP

Public agricultural research long has enjoyed high interest and dedicated support from the House and Senate Agriculture and Appropriations Committees. Those Committees have sought to insure that agricultural research and sciences have met the needs of both users in the food and agricultural system and consumers as well. Because of the major role in agricultural research played by state resources of the SAES, the Congress has viewed the nation's research as a federal-state partnership rather than a predominantly federal activity as is true in other areas. Support for SAES agricultural sciences is about 2/3 to 3/4 non-federal and 1/3 to 1/4 federal. The reverse is true for other university-based sciences.

At this time, public agricultural research is performed principally by 3 USDA agencies, (ARS, ERS, FS-R) each with a restricted mission, and by the State Agricultural Experiment Station System, quasi state agencies with broad missions, each operating under the charter of a land-grant state university. Of the nation's public agricultural research, the SAES perform about 60%; the USDA agencies, about 34%. The remaining 6% is performed by 100 or so other university-based research units.

THE MAJOR FEATURES OF THE SAES: A STATEWIDE SYSTEM IN EVERY STATE AND REGIONAL AND NATIONAL SYSTEMS TOO.

The Congress chartered the SAES in 1887 through the Hatch Act, a remarkable piece of legislation and one for which a centennial will be celebrated in Washington in less than 18 months. In that act and subsequent acts, the Congress set down 7 major provisions which now guide and give form to the SAES.

First, the Agricultural Experiment Station is a State Agricultural Experiment Station. That means it serves the State, not just the SAES nor its parent university. Second, Hatch Act federal appropriations are allocated to the SAES on a formula basis. That means every state participates. It also means lower administration costs, and decision-making at the state level. Third, States must match federal Hatch Act appropriations with state funds. That means that the federal government leverages

state funds and thus multiplies the influence of federal funds. Fourth, the Station is attached to the State's land-grant (A and M) university so that it can relate effectively to undergraduate and graduate instructional programs and extension programs in agriculture chartered there also by federal legislation. That means complementarities in programs can be exploited to increase resource efficiency. Fifth, the Station's chief administrative officer is a Director. That means accountability is centralized in one person who directs activities of the SAES. Sixth, federally appropriated resources are managed by the Station, not the USDA, but with appropriate accountability and responsiveness to national needs as identified by the Secretary of Agriculture and the Congress. That means that decisions are made on the scene by local residents but national interests are protected. Seventh, interstate, interregional, and national coordination and collaboration in research is fostered and conducted among the Stations and with USDA agencies, through a special Regional Research Fund, amounting to one quarter or more of the Hatch appropriations. That means that complementarities in programs among states and among states and USDA agencies at all levels can be exploited to increase resource efficiency.

To my knowledge, such regionally and nationally shared management of research programs exists only in agriculture and only through the SAES. Through long and often controversial, separate evolutionary processes of 100 years or more within each State, the SAES of each state has emerged with many distinctive features, but also with many features common to SAES of other states.

Differences between agriculture and other sciences in research organization and management exist at university, state, regional, and national levels. Each level provides interesting contrasts.

THE SAES IN THE UNIVERSITY SETTING

Within virtually every land grant university system, the SAES and the state's cooperative Extension Service were units legally chartered by the state legislature and located at the land grant university. Each has organized into a statewide system with headquarters units on the university campus and branch units scattered across the state. Those headquarters units

usually are organized into departments corresponding to the instructional departments of the university to which station, or extension faculty belong. Hence, station research scientists are fully integrated into university faculties. Thus, they are subject to the same performance standards as faculty elsewhere in the university. Some university scientists receive or are denied research grants from federal granting agencies according to criteria of the agency. Some judge their success on such events. But faculty always must continuously meet the performance standards of the university community to remain in good standing. Because university standards have precedence, they have higher rank to most faculty.

In many land-grant universities, the SAES and the Cooperative Extension Service are the only administrative units not organized at the discretion of the university and often the only ones budgeted separately from the general university budget. These distinctions are important.

The university, subject to approval by at least its Board of Regents, and sometimes by the state legislature organizes and reorganizes itself into administrative units and subunits as it wishes. Similarly it allocates and reallocates resources from the general university budget to administrative units and subunits at its discretion. The general university budget usually is a complex amalgam of student tuition and fees, state appropriations for higher education, income, research overhead, and gifts and grants from a variety of sources. Bureaucratic allocation of resources according to instructional work loads of colleges and departments is a common feature. However, discretionary allocations also are made.

Historical Perspectives. Prior to World War II, agricultural research in the SAES was the only university-based research to receive substantial direct support from both state and federal governments. Elsewhere in the university, major support for research came indirectly from state governments (or other university resources) by way of instructional programs. That support was to encourage graduate education and faculty development, important research-based elements of instructional programs in the sciences. Though that indirect support cannot be measured in the aggregate accurately, it is large enough to allow professors to spend on the average from 10% to as much as 30% of their work day in research and other scholarly activities. Also it is large

enough to permit such highly labor intensive faculty instructional activities as graduate classes, seminars, and research and thesis direction. That indirect support now has become extremely important to the nation's science programs and to the research programs of the federal government. It creates a permanent national flexible pool of diverse human talents and resources maintained from university resources and yet available on call to the federal government and the private sector to perform research or to train research scientists.

I call this research resource pool the "University Science Indirect Pool," or "USIP." I call the other pool containing the SAES and other directly supported research resources, the "University Science Direct Pool," or "USDP." USIP is determined largely by student demand for curricula created by the faculty. It is student driven. For example, the pool is relatively rich in scientists from the general science fields--chemistry, physics, mathematics, biology and economics--because most university curricula require students to take courses in those fields even though the number of majors in those fields may be relatively small. The pool is relatively lean in scientists from such science fields as forestry, agronomy, entomology, or electrical engineering, because only a few science curricula contain them.

USDP, on the other hand, is determined almost completely by willingness and interest of state and federal governments and private sector organizations to fund research programs. It expands or contracts in size and changes composition in direct response to resources made available for its research. It is "research market" driven.

Scientists in both pools could accomplish more with additional resources. Their needs have been and are brought regularly to the attention of the Congress.

After World War II, university enrollments exploded, thus enlarging the "indirect science pool." Four and two-year colleges acquired more Ph.D faculty, generating indirect science pools there. State governments, however, slowly but steadily fell behind in the proportion of student support they provided.

The Congress authorized sizable expansion in the research activities of many federal agencies. It created the National Science

Foundation largely to capitalize on the university indirect science pool. These research resources ended up being heavily concentrated in high overhead cost private universities and in public universities along the coasts. Universities in southern, plains, and mountain states fared least well.

The SAES expanded, too, but in different patterns. Up to 1960, federal and state resources increased, permitting most SAES to take on a broader range of problems. Since 1960, federal resources have not kept pace with inflation though they have remained relatively stable. SAES in selected states, particularly in the South have received sizable increases in state support while other SAES have expanded only modestly. A few states have reduced support.

As a consequence of the recent recession, most SAES stopped growing and many had to reduce their size as a consequence of reduced state appropriations. That trend is now reversed indicating that agricultural research is still a high priority issue.

Current Perspective and Policy Needs. Current perspectives relative to SAES operations and opportunities are captured in the following points. They also highlight policy issues.

1. Identifying Needs and Opportunities of User Groups: Inexhaustible Needs Force Rigorous Setting of Priorities.

Organized into departments largely along commodity, natural resource, human and community resource, and industrial group lines, the SAES have depended on those departments to maintain close liaison with user groups to identify needs and opportunities. Regular meetings and departmental advisory councils, annual field and research days, and other activities involving users insure that communications flow freely. More general input often is provided by the state legislature, USDA and other federal agencies, and the Congress through the Director's Office. User needs continue to far outstrip resources and force rigorous setting of priorities.

2. Responding to User Needs; Ever More Complex Problems and Faster Adoption of Discoveries.

Most states have from 15 to 40 major commodities and related industries. Most states have from 5 to 10 special topographic, soil, and climatic subregions. Simple problems are readily solved, most many years ago. With each passing year, the complexity of problems increases. That often means larger, longer, and more expensive experiments. New discoveries are adopted much more rapidly. The technology pool has little, unutilized reserve technology.

3. A Scientist as a Lone Problem Solver: Intellectual and Physical Limits of Humans

Scientists design and execute experiments that answer user needs. To solve increasingly complex problems, scientists now specialize ever more narrowly on a single aspect. To solve all aspects requires larger and larger teams. Resource limitations force reduction in the number of problems approached or in the scope of solutions.

4. Resource Availability: Always Inadequate for the Needs

Investments in public agricultural research in a state usually range from 3/4% or lower on gross sales of commodities from that state. Current investments in a scientist average about $150,000 per year. If resources were allocated to a commodity's problems on the basis of the economic importance of that commodity, only commodities producing $20 million or more sales could expect the efforts of one full-time scientist.

5. Resource Flexibility: Constraints of Long-Term Commitments and a One-Time Opportunity

Tenure commitments to specialized faculty and civil service employment standards lock in resources for many years. Thus, employment decisions serve to constrain response of SAES to changing user needs. Retirements of scientists hired as part of the post World War II expansion will provide unusual opportunity for program redirection during the next 5 years.

6. New Opportunities: New Technologies Can Increase Efficiency and Success of Research Systems

Biotechnology, genetic engineering and DNA manipulation, computer technology, sensors, automated research processes and expert systems offer new avenues to increase efficiency and success of the SAES research system.

They will be important influences in resource allocations of the next 5 years. Some have a high price tag. Others offer cost reductions.

7. Changing Roles of Public and Private Sectors in Research: New Opportunities Suggest Redefinition of Roles

Some see research as a sequential trichotomy of basic, applied and developmental activities: basic, primarily in the public sector; applied, in both sectors, and developmental, largely in the private sector. Most now see research as a complex interplay of activities drawn from a continuum of basic to developmental research. Increasing world competition in high technology fields suggest that arbitrary divisions of responsibility among sectors or limiting federal roles to support of basic research now may not be in the nation's best interests.

THE SAES SYSTEM AS A MODEL SYSTEM--A SPECIAL EXAMINATION

Because the SAES system of funding, priority setting and research management is unique, a brief examination of these activities may prove useful.

Funding The old adage "he who pays the piper calls the tune" is true in the SAES. Long-term, stable direct funding of the SAES is a most significant determinant of success. State and federal legislation establish the mission of the SAES; state and federal appropriations support that mission. Dual funding sources enable constraints on one source of funds to be addressed with the other. Because funds are "institutional", i.e., they go to the Station and not to a department or to an individual scientist in the stations, and because the Station Director is held accountable for expenditure of the funds, the Director can exercise considerable influence in allocating resources, and setting

priorities. Similarly, once allocations are made to a department, the department head also can exercise influence. Purchase of expensive equipment and sharing of it and other resources is made possible because the Director has access to a much greater pool of resources than department heads or individual Scientists

Indirect funding through instructional resources of the university can provide only a tiny base, one inappropriately constructed for needs of agriculture. Long-term cooperative agreements with USDA agencies have brought federal scientists to many states. They broaden and strengthen human resources in the state. Grants and contracts from federal agencies offer opportunities for individual SAES scientists in certain fields to expand their operating funds with complementary research investigations. Grants from industry and producers provide added resources in solving problems of concern to those groups (tables 1 & 2 provide details of SAES funding).

Appropriations are made to support the broad mission of the SAES and only occasionally are constrained. They seem to have no major weaknesses. Contracts and grants to individual SAES scientists support the mission of the granting agency and are sharply constrained. The missions of the granting agencies may not complement the SAES mission. When federal grants or contracts become a major resource in a department or to an investigator, they may cause them to lose sight of their SAES mission; and SAES resources drift off target. When industrial or producer grants become a major source, they may cause departments and scientists to focus too strongly on short term problems to the detriment of long term needs. Complete reliance on appropriations may deprive the SAES, its departments, and its scientists of the benefits of competitive entrepreneurship.

Priority Setting Priority setting is an ongoing continuous process involving SAES scientists and administrators and users of their discoveries. In only a few departments, scientists and administrators have little or no contact with users. There, the priority tides generated by the professional societies help establish priorities.

The distinction between basic and applied has little meaning to most SAES scientists. They solve problems by whatever approach is appropriate. The SAES are the nation's largest performers of basic agricultural research. About 40% of the SAES research is classified as basic.

Management When appropriately funded, SAES management draws on the best features of hierarchical management characteristic of federal agencies and the collegial management characteristic of the university. Management decisions in isolation from users are never possible.

Table 1. STATE AGRICULTURAL EXPERIMENT STATIONS

SOURCES OF FUNDING
(in $ thousands)

	1974	1979	1984
I. Federal	115,266	204,640	295,996
A. USDA	84,096	143,736	214,277
(1) CSRS	(75,482)	(124,595)	(180,950)
a) Formula	[72,229]	[112,186]	[158,365]
b) Other	[3,253]	[12,409]	[22,585]
(2) Other USDA	8,614	19,141	33,327
B. Other Federal	31,170	60,904	81,719
II. State Appropriations	243,708	406,147	591,356
III. Product Sales	32,246	46,060	61,330
IV. Industry	20,624	35,753	64,148
V. Other	12,040	25,449	46,512
TOTAL	423,885	718,048	1,059,343
Scientist Years	6,034.2	6,567.5	6,897.7
$/Scientist Year	70,247	109,333	153,623

Table 2. STATE AGRICULTURAL EXPERIMENT STATIONS

SOURCES OF FUNDING

	1974 %	1979 %	1984 %
I. Federal	27.2	28.5	27.9
A. USDA	19.8	20.0	20.2
(1) CSRS	(17.8)	(17.4)	(17.1)
a) Formula	[17.0]	[15.6]	[14.9]
b) Other	[0.8]	[1.7]	[2.1]
(2) Other USDA	2.0	2.7	3.1
B. Other Federal	7.4	8.5	7.7
II. State Appropriations	57.5	56.6	55.8
III. Product Sales	7.6	6.4	5.8
IV. Industry	4.9	5.0	6.1
V. Other	2.8	3.5	4.4
TOTAL ($ 000)	423,885	718,048	1,059,343
Scientist Years	6,034.2	6,567.5	6,895.7
$/Scientist Year	70,247	109,333	153,623

Biographical Sketch
Keith Huston

Keith Huston serves as Director-at-Large for the North Central Regional Association of State Agricultural Experiment Station Directors. Educated at Wisconsin, Dr. Huston was later employed as a professor of dairy science, specializing in dairy cattle genetics, at Virginia Polytechnic Institute and State University, Kansas State University, and the University of Minnesota. Commencing his administrative career in 1969, Dr.Huston has served as assistant and associate director of the Kansas Agricultural Experiment Station and as director of the Minnesota Agricultural Experiment Station.

Dr. Huston currently is Co-Chairman of the National Agricultural Research Committee (NARC) of the Joint Council on Food and Agricultural Sciences (JCFAS). He has served as Chairman of the Experiment Station Committee on Organization and Policy (ESCOP); Chairman of the Committee of Nine; Co-Chairman of the International Science and Education Council (ISEC) Research Committee, and President of the Agriculture Research Institute, Washington, D. C. His service on national committees and task forces includes: World Food and Nutrition Study, National Academy of Sciences-National Research Council; Panel on Agricultural Research, Office of Technology Assessment (OTA); Ad Hoc Joint Committee on Country Programs, Title XII Legislation, Agency for International Development; Commission on Undergraduate Education in Agriculture and Natural Resources, National Academy of Sciences-National Research Council.

Articles

Behavior and Productivity Implications of Institutional and Project Funding of Research

Maury E. Bredahl, W. Keith Bryant, and Vernon W. Ruttan

A behavioral model of a research scientist is utilized to develop the characteristics of the demand for institutional (IR) and project research (PR) funds. The demand analysis implies a trade-off between the allocative and productive efficiency of IR funding and the research output mix of PR funding. The model is used to evaluate the formula and competitive grant funding of U.S. agricultural research. We conclude that national research policy should be cast in terms of the relative mix of the two systems of support, not in the absolute merits of either system.

Key words: agricultural research, allocative efficiency, demand for research funds, research-funding policy.

In this paper, we analyze the implications of two alternative research-funding schemes. The first, institutional research (IR) support systems, provides funds to support the research program of a particular research institution. Typically, the funds are not targeted to research areas. Rather, the selection of research areas is made by the administrators of the research institution or individual researchers. The second, project research (PR) grant system, provides support through project grants to individual scientists or research teams. The allocation of research effort typically is determined by the granting agency.

Examples of institutional support for research are numerous. IR was the traditional instrument employed to support federal and state mission-oriented research in the fields of defense, agriculture, natural resource exploration, industrial standards, and related areas prior to World War II (Dupree, Stein). The program of federal support for agricultural experiment stations on a formula basis is a prototype of the institutional research system.[1]

In the private sector, the Ford Foundation has provided institutional support for the research program of Resources for the Future since the early 1950s. Institutional grants were also made to Social Science Research Council to enable the Council to operate the Foreign Area Fellowship Program—a program of project grants. The U.S. Agency for International Development (USAID) provides institutional grants in support of the research programs of the international agricultural research centers which are part of the Consultative Group on International Agricultural Research.

The competitive grant program of the National Science Foundation, in which grant requests are received from individual scientists or research teams and evaluated by peer panels, is a prototype of the project research system. Most of the major foundations and a number of federal agencies operate project research grant programs in addition to IR programs. The project research grant mechanism emerged as a major instrument for linking academic research with mission-oriented federal agencies in the late 1940s and early 1950s (Stein).

The authors are, respectively, assistant professor, Department of Agricultural Economics, University of Missouri; professor, Department of Consumer Economics and Housing, Cornell University; and professor, Department of Agricultural and Applied Economics and Department of Economics, University of Minnesota.

The authors have benefited from comments on an earlier draft of this paper by Emerson Babb, Robert Evenson, Walter Fishel, Edward Foster, Don Hadwiger, R. J. Hildreth, Keith Huston, Yoav Kislev, Michael Lea, Willis Peterson, Jean Robinson, Roland Robinson, Theodore W. Schultz, and Burt Sundquist.

[1] Funds allocated to the states under the Hatch Act, except for funds reserved for cooperative regional research efforts, are allocated to the state agricultural experiment stations by a formula based on the number of farms and the size of the rural population in each state. The several sources of federal funds for state agricultural research are identified in the latest annual report of the USDA Cooperative State Research Service. Factors affecting the support for state agricultural experiment stations have been analyzed by Huffman and Miranowski, Peterson (1969), Heady (1961, 1962), and Dalrymple (1962).

Copyright 1980 American Agricultural Economics Association

Each of the two research management schemes has strengths and weaknesses. The system constraints and the reward systems are very different under IR and PR research management. The next section of this paper presents an analysis of the behavior of individual scientists in an environment characterized by the availability of centralized project grant systems and decentralized institutional grant systems. We then examine the behavior of research administrators under the two research support systems. Finally, we attempt to draw some inferences from the behavior of research scientists and administrators under the two systems for research system efficiency. The analysis presented here provides a theoretical framework for the empirical evaluation of the gains and losses from the two systems of research management.

The Research Scientist

What objectives does the individual research scientist attempt to maximize? And how does the project (PR) and institutional (IR) research grant systems impinge on the behavior of the individual scientist?

The research scientist has been depicted as both hero (Stakman, Bradfield, Mangelsdorf) and villain (Berry). Our perspective is more modest. The typical research scientist is, as a result of inclination and conditioning, prepared to accept a rather high degree of deferred gratification within the professional reward system. In the immediate postdoctoral years, the scientist is usually willing to defer immediate financial reward for an appointment which assures continued professional development—preferably documented by the accumulation of evidence of research productivity in the form of published papers. If professional productivity is accompanied by reasonable advancement in rank and earnings, the initial research orientation is reinforced. If productivity lags or is not accompanied by advancement in salary or rank, there often is a shift in emphasis toward research that is valued by clienteles other than professional colleagues. This shift toward more applied research also may be associated with a transfer to another institution whose program is oriented more toward applied research. During this process the mid-career scientist may also develop certain entrepreneurial skills. These skills may run in the direction of capacity to generate research support from funding agencies and/or to mobilize the interest and the energies of colleagues to focus their efforts around problems of scientific or technical diversification which require a team effort. Development of entrepreneurial skills often comes at the expense of disciplinary capacity and direct involvement in research.

This description is, of course, highly simplified. And our ability to model is inadequate to deal with even this simplified view. However, we are able to identify several key elements of the individual scientist's objective function that appear directly relevant to the scientist's behavior under the institutional and project grant systems. (Since developing the model, our attention has been drawn to a similar model developed by Becker. His models are, however, designed to address different questions.)

The simplified behavior model that we have developed has the following characteristics:

(*a*) Each researcher maximizes some utility function by simultaneously allocating time between teaching, entrepreneurial activities such as seeking research support, actively working on research, and leisure. The use of leisure to represent nonwork related activities is a common methodological device.

(*b*) Research output is determined by the level of research support available to the researcher and the time spent actively working on research. The researcher faces diminishing returns both in the production of research funds and in the production of research.

(*c*) The transaction costs incurred by the individual researcher in obtaining project research support are greater than those incurred in obtaining institutional research support. However, the level of available IR support may be a binding constraint. That is, IR funds may be rationed and become unavailable before the researcher achieves the equilibrium allocation of time which maximizes utility.

(*d*) Income is a positive function of research output and some measure of teaching and/or extension (or public service) output depending on the way in which a particular scientist's appointment is defined.

Our goal is to determine the characteristics of the demand for research funds. Although several factors influence the individual scientist's demand for research funds, only the cost of obtaining grant and formula funds is considered. Factors held constant include the maximum amount of institutional funds available,

the preferences (utility function) of the researcher, the production function of research output, and the rewards from research output (the income production function). Varying the cost of obtaining research funds allows examination of the impact of alternative research management schemes. Only highlights of the model are presented but a detailed description and mathematical exposition is found in Bryant (available from the author upon request).

The results of the model depend critically on the hypothesis that the transactions cost of the PR system is significantly higher than those of the IR system. In other words the marginal productivity of time spent seeking institutional research funds is significantly higher than that seeking project research funds. Most university scientists can quote examples of the colleague who has spent much more time preparing grant requests for the support of summer research than was spent actually carrying out the grant-supported research. It also seems consistent with experience that the greater the degree of centralization of research management, the greater the costs of grant seeking and the costs of the review and allocation process.

The research scientist maximizes utility by allocating his time among active research, grantsmanship, and leisure (all other activities). Thus, the derivation of the demand for research funds (which reflects the allocation of time to grantsmanship) is similar to the derivation of the demand for a consumption good by the utility-maximizing consumer. However, research funds are an input in the production of research output. The derivation of the derived demand for research funds has certain similarities with the derivation of the derived demand for an input by a profit-maximizing firm.

Before deriving the implications of alternative research management programs, the implication of limited IR funds and different production functions for PR and IR funds are developed. The marginal product of time allocated to production of IR funds exceeds that of time allocated to production of PR funds. Logically, any time allocated to producing research funds will be allocated first to IR fund production. Time will be allocated to producing PR funds only upon exhausting available IR funds.

The assumption of greater cost to obtain PR funds coupled with the limitation on IR funds implies the marginal product of time allocated to production of research funds is a step function. The marginal product is illustrated in figure 1. The marginal product curve is derived simply by increasing the amount of time allocated to producing research funds. The conditions for utility maximization are not required to illustrate the characteristics of the marginal product curve.

Initially, any time allocated to producing research funds (T_k) will be used to produce IR funds (T_h). This maps the *ab* portion of the marginal product curve. At *b*, the amount of IR funds available (requiring a time allocation of T_h^{max}) is exhausted. Hence, additional allocations of time can produce only PR funds (T_g). But the marginal product of the first unit of time producing PR funds is less than the last unit producing IR funds. The differential costs result in the discontinuous portion of the curve, labeled *bc*. Allocation of time to producing research funds beyond T_h^{max} produces only PR funds mapping the *cd* portion of the marginal product curve.

To this point, the optimum allocation of time has not been considered. The desired statement of the demand for research funds reflects alternative research management schemes. The cost of obtaining research funds is varied by shifting the marginal product curve illustrated in figure 1. A reduction (increase) in the cost (marginal product) of obtaining research funds shifts the curve upward. To determine the characteristics of the demand for research funds, the marginal products of time producing formula and grant funds are exogenously and proportionately varied.

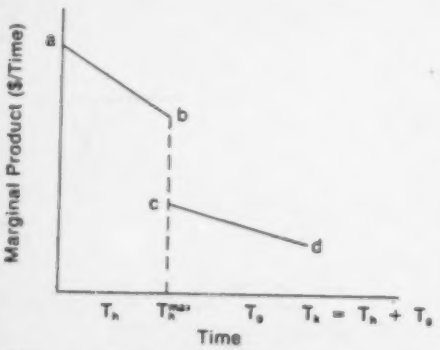


Figure 1. The marginal product of time allocated to obtaining research funds

In the analysis, increases in the marginal productivity of time allocated to producing research funds is synonymous with a reduction in the cost of obtaining research funds. Cost in this context may be thought of as the amount of time in other activities (and the associated income and utility) that must be foregone in order to obtain research funds. That cost reflects the research management system.

Initially, assume the cost (marginal product of time) of research funds is relatively high (low). At equilibrium, relatively little time is allocated to producing research funds (K). Hence, a relatively small amount of research funds will be demanded. Further decreases (increases) in the cost (marginal product) will increase the demand for IR funds until all available IR funds are exhausted (K_h^{max}). This maps the *ab* portion of the demand for research funds illustrated in figure 2.

Further decreases in the cost of research funds will not increase the quantity of research funds demanded. The optimum allocation of time to producing research funds occurs along the discontinuous part of the marginal productivity curve (*bc* in figure 1). Hence, the discontinuous characteristic of the marginal product curve maps the *bc* portion of the demand curve for research funds.

Still further decreases in the cost of research funds induce the allocation of time to producing PR funds (K_g). This maps the *cd* portion of the demand curve for research funds. The effective demand for research funds is *abcd* as illustrated in figure 2. The implications of the step function characteristic of the demand for research funds are now developed.

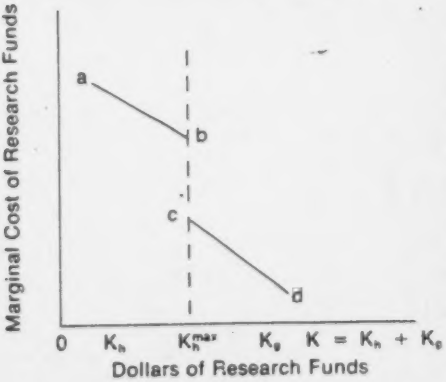


Figure 2. The individual's demand for research funds

First, at any institution there will be those scientists with so low a demand for research funds that they are not constrained by the limit on IR funds. These will be individuals who are very productive in nonresearch activities relative to research and those with high marginal products of labor in research relative to the marginal product of research funds. The former will specialize in teaching, extension, and administrative activities, while the latter will be the "pencil and paper" theorists. Both will operate within the *ab* portion of the demand for research funds and will not be affected by K_h^{max}. Of course, the more affluent the institution, the larger K_h^{max} likely will be for any individual. We would expect, therefore, interinstitutional differences in the proportion of faculty operating in the unconstrained *ab* portion of the curve. Depending on the allocating conventions of experiment stations, some fields may be allocated relatively more than others and so the scientists within these fields likewise will be less constrained.

Second, there likely will be a number of individuals at any institution who operate in the *bc* portion of the demand for research funds curve. Such individuals would demand more IR funds were such funds not rationed. But, they demand no competitive funds (K_g) because the marginal cost of K_g (the marginal value of the foregone leisure) is greater than the increment to income the added funds would bring. The number of such researchers who are thus "immobilized" depends, of course, on the length of the discontinuity, *bc*. It will be longer (and thence the frequency of immobilized researchers greater), (*a*) the greater the difference in the marginal costs of IR and PR funds, (*b*) the better substitutes research funds and researcher labor are in research, and (*c*) the better substitutes teaching, extension, administration, and research activities are in yielding income to the individual.

Third, within the range of the discontinuity, *bc*, while the demand for research funds is invariant, the amount of research done is not. Because he is barred from PR funds by their high marginal cost, the researcher may substitute his own labor for research funds and continue to increase research output, subject, of course, to greater diminishing returns than otherwise would exist. The labor intensity of the research, then, will increase as a result of

the limitation on IR funds and the high cost of competitive funds.[2] This labor intensity with respect to the primary researcher's labor also may involve changes in the research output mix: more theoretical work, more use of secondary data, smaller and fewer experiments, smaller and fewer instances of primary data generation as the research becomes more labor-intensive.

Fourth, another impact of the discontinuous demand for research funds is to increase the labor devoted by the scientist to other aspects of his (her) appointment: teaching, extension, administration. Consulting activities also can be expected to increase. Again, this bias toward nonresearch activities will occur to the extent that the individual has a positive demand for income (is not in the backward-bending part of his supply curve of labor), and the marginal wage rates for the nonresearch aspects of his (her) appointment are positive. Therefore, not only does the limit on IR funds and the high cost of competitive funds increase the labor intensity of the research enterprise of those caught in the discontinuity, it also has the effect of increasing the labor intensity of all other aspects of the individual's job.

Fifth, those not caught on the discontinuity and who have high enough demand for income (consumption) compete for PR funds and operate on the *cd* portion of the demand for research funds curve. The research outputs and incomes of such individuals are higher than those who operate on the *ab* and *bc* portions of the demand curve for the research funds. Because the marginal cost of PR funds is much higher than the cost of IR funds, the research funded with IR and PR funds will be more labor-intensive than the research of those operating on the unconstrained, *ab* portion of the curve. Whether the research done on the *cd* portion of the curve is more or less labor-intensive than those caught in the discontinuity depends on the difference in the marginal costs of PR and IR funds: the greater the difference, the more likely the research of those caught in the discontinuity will be more labor-intensive than those demanding PR funds. One way of looking at this is that as the difference between the costs of the two types of funds increases, more of the scientist's time must be devoted to grantsmanship and less to direct research activities if he (she) is to compete for PR funds.

Sixth, it is likely that a reduction in IR funds with the consequent increased stringency with which remaining IR funds would be rationed among researchers (a shift to the left of K_A^{max} in fig. 1) will increase the difference between the marginal costs of IR and PR funds. As IR funds are increasingly rationed, more individuals will be pushed from the *bc* to the *cd* portion of the demand for funds curve and will compete for PR funds. The increased number of competitors for PR funds will drive down the probability of acceptance of any given proposal and so raise the marginal cost of grantsmanship. A transfer of the reduced IR funds to PR purposes (as the USDA proposed in 1978) will increase either the number of PR projects funded or the level of funding per project and so increase the expected yield per proposal. The net effect of these two changes is unclear. If academics are as risk-averse as recent writings on the economics of academic tenure and retirement suggest, the decline in the probability may well be more important than the increase in PR funds. If so, the marginal cost of PR funds will rise. A possible result of transferring funds from IR to PR purposes, therefore, will be to increase the proportion of researchers immobilized in the *bc* portion of the curve.

Seventh, it is worth noting that given a distribution of grantsmanship skills among scientists, the greater the difference between the marginal costs of IR and PR funds, the greater the likelihood that specialization of function will arise among scientists. The more skilled as grantsmen will specialize in the activity doing little or no actual research.[3] And with the PR funds, they will hire scientists relatively more skilled in research to which they will allocate research funds.

The Research Administrator

An assessment of implications of a project research grant system relative to an institutional research grant system must consider the ef-

[2] In this instance and hereafter when labor intensity is discussed, it is researcher or project director labor that is being referred to. Within the limits of IR and PR funds, other labor (graduate students, postdoctoral fellows, research assistants, secretaries, and the like) may be employed to carry out particular facets of the research.

[3] There is some evidence to the effect that younger scientists are more active in journal publication than older scientists and that the marginal value of a journal article, in terms of income, declines with the scientist's age (Peterson 1973, p. 14).

fects of the two systems on the behavior of the individual scientist. In this section we suggest how the project and institutional research grant systems impinge on the behavior of the research administrators. We shall be particularly concerned with the impact on the behavior of the director of an agricultural experiment station, research center, or laboratory located within a university environment.

Our description of the objective function of the research administrator is largely intuitive. Kaldor (1971, 1978) repeatedly has pointed to the dearth of systematic knowledge about the decision-making processes used by research administrators. Most of the knowledge that we do have is based on casual observation and introspection. Nevertheless it does seem feasible to specify some of the elements that enter into the decisions of research administrators and scientists.

The typical research manager tends to have a view of the world which places a heavy weight on the value of new knowledge and new technology and places a low weight on both the direct and indirect costs of research and of technological change. The administrator visualizes an almost "endless frontier" waiting to be discovered, with limited financial, physical, and professional resources. The administrator's standing, both within his (her) own institution and among outside collegiate and clientele constituencies, is directly related to the ability to assemble or develop a research staff that is recognized for the quality of its work or its value to clientele constituencies. Within public sector institutions, where the salary structure is somewhat bureaucratically determined and has little flexibility at the top, prestige considerations carry greater weight. In the private sector, where the output of the research laboratory is evaluated more directly in terms of the enhancement of the firm's profits, productivity is given more weight.

The net effect of these considerations leads a research director to measure success in terms of the capacity to acquire additional resources and the ability to utilize these resources productively. The measurement of the quality or the value of research output at the individual scientist or research team level is highly subjective, and the management of research enterprises is highly collegial. These factors tend to lead to an emphasis on the quality of the major input, professional personnel, relative to the value of research output. Emphasis on more effective monitoring of research output is greatest in those cases where there is strong clientele pressure. Clientele pressure on research management is reasonably strong in state and federal agricultural research programs because of the close feedback loop between farmers, legislators, and research institutions (Hayami and Ruttan, Guttman).

The above description of the elements that enter into the objective function of the research administrator or manager is not inconsistent with the utility function of the bureau manager that has been suggested in the literature on bureaucratic behavior (Niskanen; Ruttan). In that literature it is assumed that the bureau manager's utility is a function of (*a*) the bureau's output, (*b*) the bureau's discretionary budget. In the case of the agricultural experiment station or the agricultural research institute, we can interpret bureau size in terms of research staff and the output of applied research that is valued by the research institution's clientele. Discretionary budget can be interpreted in terms of funds to support more fundamental (basic or supporting) research and for related professional activities (seminars, symposiums) that serve to enhance the capacity of the research staff or the prestige of the research unit. It represents funds that are not required to meet salaries and other overhead items. This description of the utility function of the research manager involves an even greater simplification of a complex reality than our description of the utility function of the individual research scientist. It does, however, appear to capture important elements of the research manager's motivation.

If incremental growth in research funding is primarily in the form of project rather than institutional research support, as suggested in the introductory section, one effect will be to reduce the discretionary resources available to state experiment station directors. A higher proportion of institutional support funds will have to be devoted to salary and overhead items. Capacity to mobilize resources for problems of significance at the state or regional level will be reduced.

We are now ready to combine our analysis of the effects of the institution research grant (IR) and the project research grant (PR) systems on the behavior of the individual scientist and research administrator, on the efficiency

or the productivity of the research system, and on the strategy alternatives available to research administrators.

Some Research Management and Policy Implications

The goal of a research management system is the production of the socially desired mix of research output at the minimum social cost. Our analysis suggests that the institutional research management system entails lower transactions costs than the project research management system. On the other hand, the project research management system enables the control of the mix of research output at a central (national) level. Advocating one system in preference to the second involves the trade-off between central control and system efficiency.

Research Efficiency

It would be surprising, however, if optimization of the objective functions of research scientists and administrators would lead under most circumstances to system efficiency. System efficiency is a function of the institutional environment, including the structure of incentives and constraints, in which scientists and administrators carry out their professional responsibilities. When we examine the implications for the behavior of scientists and research administrations under the IR and PR systems, some rather clear-cut empirical generalizations concerning system efficiency emerge.

First, the external PR grant system diverts efforts by individual scientists from research to grant seeking and related entrepreneurial activities (Foster 1979a, b). This is why the PR portion (section *cd*) of the individual researcher's demand for funds lies below the IR portion (section *ab*). More directly to the point, in 1978 the U.S. Department of Agriculture (USDA), which administered a competitive grant program of $15 million, received more than 1,100 research proposals involving funding requests for over $200 million (USDA 1978b). Similar ratios have been noted for other grant programs (Leopold). In addition to the time devoted to the preparation of unfunded grant proposals, substantial time also is devoted to peer review and administration.

A major structural feature of the competitive grant system clearly induces excessive allocation of scientific effort to grant-seeking activity. To the individual researcher, the supply of PR funds appears relatively elastic (with respect to effort devoted to grant seeking). Each individual project is small relative to the resources available to the granting agency. In the aggregate, however, the supply of research funds is relatively inelastic in the short run. An increase in the number of projects submissions results in an increase in the share of research resources devoted to grant seeking relative to research and an increase in the bureaucratic resources devoted to grant management. It also may result in smaller average size of individual grants and fragmentation of research effort.

Second, in a system which limits institutional support primarily to personnel support for core scientific staff (such as tenured professors) and capital equipment (such as laboratory space and computing equipment), incremental research costs must be covered by project grants. Over time, a research institute committed to solving a particular scientific and technological problem, adapting soybeans to shorter growing season environments for example, may find its staff responding more to priorities of external funding institutions rather than concentrating its effort on the crop improvement mission. It is not difficult to imagine a situation where a university administration begins to value its agricultural (or space science) research capacity less for the significance of the scientific and technological knowledge it produces than for the overhead generated by research grants or contracts.

This problem appears to be most acute in situations in which institutional research support has been closely linked to, or hidden by, reduced teaching loads. In the 1950s and 1960s many universities used expansion of undergraduate education to support the expansion, almost surreptitiously, of their institutional research support (Keyfitz). This has created two important problems in a period of declining or shifting undergraduate enrollment. Institutional research support by discipline or problem area expanded in response to differential rates of growth in undergraduate enrollment. Likewise during a period of declining or shifting enrollment, institutional support is eroded

57-279 O - 87 - 9

for considerations unrelated to scientific opportunity or technological priority. As noted earlier, institutional support for agricultural research has not been as closely coupled to undergraduate enrollment as in many other areas. There are, however, substantial pressures in some states from university administrators and state legislative committees to conform to university-wide standards with respect to student-teacher ratios. In the future, effective allocation of institutional research resources will require the development of budgeting mechanisms that more effectively uncouple the institutional support for teaching and research activities.

Research Mix

One major advantage that is sometimes claimed for a project grant system is its flexibility in redirecting research effort into areas of new scientific interest or technical concern. Research systems that rely primarily on institutional support have been characterized as limited in their capacity to reallocate scientific and financial resources from traditional areas of concern or staff capacity to new areas. The state agricultural experiment stations in the United States have been criticized for devoting excessive attention to problems of increasing food and fiber production and as unresponsive to environmental and human concerns in a period of changing social values (Paarlberg). In the United Kingdom, the national agricultural research institutes were criticized in the Rothschild report for devoting too much attention to basic research and being unresponsive to the needs of the farmer and the food industry (Ulbricht).

A second argument that is sometimes made for a competitive project grant system is that it creates a marketlike environment for both talent and ideas. This argument frequently is coupled with arguments in favor of a peer review system to assure competent scientific judgment and effective quality control in the allocation of research resources (Cole, Rubin, Cole; Bowers; Gustafson).

Both arguments have a great deal of intuitive appeal when used to support the proposition that a centralized project research grant is itself a powerful force for conformity. We have great difficulty, for example, visualizing how a peer panel might have reacted in 1900 to a proposal from a young physicist named Einstein, who had just published his first professional paper, for support of a project which had as an objective the development of a unified theory embracing mechanics, optics, and electrodynamics—and without resort to conventional laboratory technique.

The Management of Research at SAES

The sources of funds available to U.S. state agricultural experiment stations have consisted primarily of federal funds appropriated to the states on a formula basis and of funds appropriated for agricultural research by state legislative bodies (table 1). Although federal "formula" funds are granted to the state on a matching basis, in recent years most states have supported agricultural research at a level that substantially exceeds the federal matching requirements. In addition to federal and state funds, many state agricultural experiment stations also obtain substantial contract and grant support from private industry, private foundations, the U.S. Department of Agriculture, and from other federal and state sources. The contract and grant support from other federal agencies and other sources has tended to increase slightly more rapidly than the traditional sources of funds.

The last decade has been characterized by a growing lack of confidence in research decision-making processes (Berry; Bonnen; Hadwiger; Mayer and Mayer; Meier; Paarlberg). In the United States the agricultural research establishment has been viewed as unresponsive to environmental, distributional, and humanitarian concerns. New clientele groups have attempted to move concerns such as nutrition, rural development, environmental impact, soil conservation, and the problems of hired workers higher on the research agenda.

Partially in response to this criticism, Congress established a federally funded, competitive, research grant program open to all scientists and administered by the Competitive Research Grants Office of the USDA Science and Education Administration.[4] The FY 1978 appropriation act made a total of $15 million available for competitive research grants. The executive budget for FY 1979 proposed that the competitive grants program be increased by an additional $15 million (table 2). This was

[4] A program of special grants that were competitive among state agricultural experiment stations was initiated in 1970. These funds rose from $2.8 million in 1970 to $16.2 million in 1979 (table 1).

Table 1. Amount and Relative Importance of Federal, State, and Other Funding Sources for State Agricultural Experiment Stations, 1967 and 1977

	1967		1977	
	Amount[a]	Percent	Amount	Percent
Federal sources				
Science and Education Administration (USDA)[b]	53.8	23.1	118.8	19.1
Cooperative Grants and Agreements (USDA)	10.3	4.4	12.6	2.0
Other federal agencies	24.1	10.3	55.6	8.9
	88.2	37.8	187.0	30.0
State sources				
Appropriations	118.6	50.8	341.2	54.9
Sales	13.5	5.8	39.1	6.3
	132.1	56.6	380.3	61.2
Other sources	13.1	5.6	54.6	8.8
Total	233.4	100.0	621.9	100.0

Source: USDA CRIS printout. (FY 1977 data are preliminary. FY 1978 and FY 1979 are not yet available.) The authors are indebted to Roland Robinson of the USDA Science and Education Administration for assistance in obtaining the CRIS data.
[a] Amounts are in hundred thousands of dollars.
[b] Funds received by states differ from funds appropriated by the amount of direct and indirect federal administrative charges.

offset by a reduction of approximately $11 million in Hatch Act formula funding plus reductions of approximately $1.0 million in McIntire-Stennis Cooperative Forestry Research, $2.0 million in special research grants, and $1.5 million in rural development research (USDA 1978a, c; Strobel). The 1979 appropriations act finally passed by Congress restored the cuts in Hatch Act funds that had been recommended by the administration and continued the competitive research grant program at the $15.0 million level. The executive budget for FY 1980 proposed a continuation of Hatch funding at the FY 1979 level and an increase in the competitive grants program from $15.0 to $30.0 million. The FY 1980 appropriations, however, increased Hatch funding by $9.5 million and the competitive grant program by only $1 million.

Strong support for a program of competitive

Table 2. Funds Appropriated for Agricultural Research under Cooperative Research Programs of the USDA Science and Education Administration

	1977		1978		1979		1980 Budget	
	Amount[a]	Percent	Amount	Percent	Amount	Percent	Amount	Percent
Cooperative research								
Hatch Act[b]	98.0	76.0	109.1	69.0	109.1	62.6	118.6	62.8
— Regular	73.1	56.7	81.1	51.3	81.1	46.5	87.9	46.5
— Regional	21.7	16.8	24.5	15.5	24.5	14.0	26.9	14.2
McIntire-Stennis[c]	8.2	6.4	9.5	6.0	9.5	5.4	10.0	5.3
1890 Colleges and Tuskegee Institute	13.4	10.4	14.2	9.0	16.4	9.4	17.8	9.4
Special research grants	6.3	4.9	7.2	4.6	16.2	9.3	17.7	9.4
Competitive research grants	—	—	15.0	9.5	15.0	8.6	16.0	8.4
Animal health and disease	—	—	—	—	5.0	2.9	6.0	3.2
Rural development	1.5	1.2	1.5	0.9	1.5	0.9	1.5	0.8
Federal administration	1.7	1.3	1.7	1.1	1.7	9.7	1.5	0.8
Total	129.0	100.0	158.2	100.0	174.4	100.0	189.0	100.0

Source: USDA, SEA, and CSRS memoranda to state agricultural experiment station directors
Note: Prior to 1978 the Cooperative State Research Service (CSRS).
[a] Amounts are in hundred thousands of dollars.
[b] Total includes regular and regional funds distributed to states plus federal administration and penalty mail.
[c] Cooperative forestry research.

project research grants to be administered by the USDA had been made in two reports sponsored by the National Research Council (1973, 1977). The National Research Council recommendations reflected, in part, a judgment that the productivity of agriculture and agriculturally related research could be enhanced by making USDA research support available to scientists in departments and institutions that had not been eligible for support under the formula-funding arrangements.

Administrative officers and scientists at the state agricultural experiment stations also had been generally supportive of the move to expand funds for competitive grants (Babb). Both the National Research Council and the leadership of the state experiment stations, however, had expected that an expansion of funds for competitive research grants would take place in an environment of expanded support for agricultural research. Apparently they did not anticipate the trade-off between the competitive grant and formula funding that emerged in the FY 1978 executive budget proposal.[5]

The argument for expanding support for agricultural research typically has drawn on two sources of support. Agricultural scientists and science administrators have pointed to the technical constraints that must be overcome to meet future food and fiber requirements. They also have argued that technical change leading to lower production costs represents one way of balancing the conflicting claims of farmers for higher incomes and of consumers for restraint in food price increases. Economists have buttressed these arguments with an expanding body of empirical research which has documented the high rates of return to past agricultural research (Boyce and Evenson; Bredahl and Peterson; Arndt and Ruttan). In recent years, they also have worked closely with research administrators to provide *ex ante* rate of return projections.[6] Both the constraint and the rate-of-return approaches suggest substantial underinvestment in agricultural research both in the United States and in most other countries where such studies have been conducted.

Evaluation of Current Research Policy

We have noted that the effect of a system which appears optimal to the individual scientist or to the individual research manager in a world characterized by limited institutional support and substantial project research support alternatives is to (*a*) induce both excessive allocation of professional resources to grant seeking and (*b*) contribute to the disintegration of the capacity to undertake major mission-oriented applied research programs. These two sources of inefficiency can be reduced by utilizing an institutional research strategy as the primary device for the support of mission-oriented applied research and for basic research which directly relates to the needs of an applied research program.

There is substantial evidence to support the claim of efficiency for the institutional support system. High rates of return have been attributed to the state and federal agricultural research systems in the United States, to a number of older research institutions in former colonial countries (such as the Rubber Research Institute of Malaysia), and to the older units of the CGIAR-sponsored international agricultural research system (Evenson; Evenson, Waggoner, Ruttan). It would be extremely difficult to imagine that the long-term research effort required to develop the high-yielding clones which have revolutionized productivity in the Malaysian rubber industry could have been accomplished on the basis of a series of project grants from a colonial research secretariat in London.

The inferences drawn from agricultural research are consistent with the experience of a number of highly productive industrial research programs. Mansfield et al. (p. 157) have documented rates of return to industrial research in the same range as the rates of return to public sector agricultural research. The more productive private research programs typically have been those which have combined long-term sustained support by a firm with a sufficiently broad product line to be

[5] Dr. M. Rupert Cutler, Assistant Secretary for Conservation, Research, and Education, USDA, appeared to be surprised by the results of his own budgeting efforts. In response to committee questioning on this point he responded (p. 91, 92), "That apparent relationship was unintended. By that I mean the relationship between beginning a competitive grant research program open to all agricultural scientists and the level of the Hatch Act budget request." Cutler went on to explain that many of the programs of the USDA (entitlement and regulatory programs) are legislatively determined. Given a budget ceiling, the remaining funds available for agricultural research programs are fixed. Thus the only available method to initiate the competitive grants system was the reduction of other research areas.

[6] For a review of the methodologies for estimating *ex ante* values of return see Fishel, Puterbaugh, and Shumway. For an attempt to develop *ex ante* rate-of-return estimates see Araji, Sim, and Gardner.

able to utilize a substantial share of the product of a major "in-house" research program (Mueller).

Finally, one can point to the productivity of a number of long-term institutional research support activities by the private foundations. The support by the Carnegie Institution for the fundamental studies on inheritance in maize by George H. Schull is a classic example (Sprague). The Rockefeller Foundation support for the research program of the Office of Special Studies in the Mexican Ministry of Agriculture over several decades (from the mid-1940s to the early 1960s) established the basis for the research program of international research centers which are part of the Consultative Group on International Agricultural Research (CGIAR) system. The Ford Foundation institutional support for the research program of Resources for the Future has been a major factor in establishing resource economics as a major field of economic research in the United States.

Qualifications and Conclusions

Long-term institutional research support also can become a source of inefficiency. Institutional research programs are subject to the danger of becoming too conventional or of losing a sense of urgency with respect to their mission. We noted earlier that project grant support has been defended on the basis that it forces a research system to become more responsive. We find no fault with this argument as long as project research support remains relatively small—as long as its impact is to encourage the exploration of new opportunities within the broad research mission of an institution

There are also other devices for offsetting geriatric tendencies in a mature research institute. The development of cost-sharing arrangements between public research institutes and clientele groups, or user representation on boards of directors or advisory committees, and use of periodic peer review panels are among the possibilities. An important factor in the case of the state agricultural experiment stations has been their location within a university environment. The interaction between graduate training and research and the opportunities to draw on professional capacity in related fields have contributed to research productivity.

Another argument which must be dealt with is whether a competitive PR support system is an effective way of taking advantage of the research capacities that exist outside of institutionally funded research programs. A major argument in favor of the new USDA project grant program is that it would be able to draw on professional resources in departments that do not receive experiment station funding and in institutions that were not part of the land grant system. An analogy often is made with the project grant programs of the National Science Foundation, which frequently supports the research of individual scientists in institutions which have very little institutional research capacity.

This argument is only partially compelling. The United States has been reasonably successful in evolving a dual system of colleges and universities in which those institutions that are capable of organizing effective graduate training and research activities are sharply differentiated from those that do not possess such capacity. The major research universities probably have greater capacity to manage efficiently a program of research grants based primarily on the quality of individual projects than a central granting agency such as the USDA or the National Science Foundation.

For the colleges and universities which do not have substantial graduate programs, faculty research must be justified primarily on the basis of contribution to the viability of the teaching programs. A limited commitment of faculty effort to scholarship and research contributes to the vitality of undergraduate teaching programs. Even in institutions that are primarily committed to an undergraduate education mission, our experience on university and agency research review panels leads us to believe that institutional support for a program of small grants would be more efficient than a grant program that is centralized in a Washington agency.

In our view, the current argument about the merits of institutional (IR) and project (PR) research support more appropriately is cast in terms of the relative mix of the two systems of support than in the absolute merits of either system. We do, however, insist that the issue of efficiency in the allocation and use of research resources is important. The productivity of agricultural research judging from historical rates of return has been high. This places a heavy burden on those who would argue for

the shift of resources from institutional to project support to demonstrate that such a shift would either enhance the productivity of the existing level of research support or draw substantial new resources into the agricultural research system.

[Received May 1979; revision accepted December 1979.]

References

Araji, A. A., R. V. Sim, and Richard Gardner. *Returns to Public Investment in Agricultural Research and Extension in the Western Region*. Dep. Econ., University of Idaho, Jan. 1978.

Arndt, Thomas M., and Vernon W. Ruttan. "Valuing the Productivity of Agricultural Research." *Resource Allocation and Productivity in National and International Agricultural Research*, ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 3–25. Minneapolis: University of Minnesota Press, 1977.

Babb, Emerson M. *Marketing Research at State Agricultural Experiment Stations: Problems and Possible Solutions*, pp. 12–25. Purdue University Agr. Exp. Sta. Bull. 150, Jan. 1977.

Becker, William E., Jr. "Professional Behavior Given a Stochastic Reward Structure." *Amer. Econ. Rev.* 69 (1979):1010–17.

Berry, Wendell. *Culture and Agriculture: The Unsettling of America*. New York: Avon, 1978.

Bonnen, James T. "The Crisis in the Traditional Roles of Agricultural Institutions." *Agricultural Policy in an Affluent Society*, ed. Vernon W. Ruttan, Arley D. Waldo, and James P. Houck, pp. 48–62. New York: W.W. Norton & Co., 1967.

Bowers, R. "The Peer Review System on Trial." *Amer. Scientist* 6(1975):624–26.

Boyce, James K., and Robert E. Evenson. *National and International Agricultural Research and Extension Programs*. New York: Agricultural Development Council, 1975.

Bredahl, Maury E., and Willis L. Peterson. "The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations." *Amer. J. Agr. Econ.* 58(1976):684–92.

Bryant, W. Keith. "The Faculty Member as a Teacher and a Researcher: A Mathematical Model with Implications of Grant Versus Institutional Research Support." RP80-1, Dep. Consumer Econ. and Housing, Cornell University, Jan. 1980.

Cole, Stephen, Leonard C. Rubin, and Jonathon R. Cole. "Peer Review and the Support of Science." *Scientific Amer.* 237(1977):34–41.

Cutler, M. Rupert. "Statement." *Appraisal of Title 14 (Research), Agricultural Act of 1977*, pp. 91, 92. Hearings before the Subcommittee on Department Investigations, Oversight and Research, of the House Committee on Agriculture, 23 Feb. 1978.

Dalrymple, Dana. "Comment on 'Public Purpose in Agricultural Research and Education'." *J. Farm Econ.* 44(1962):444–53.

Dupree, A. Hunter. *Science in the Federal Government: A History of Policies and Activities to 1940*. Cambridge, Mass.: Harvard University Press, 1957.

Evenson, Robert E. "Comparative Evidence on Returns to Investment in National and International Research Institutions." *Resource Allocation and Productivity in National and International Agricultural Research*, ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 237–64. Minneapolis: University of Minnesota Press, 1977.

Fishel, Walter L., ed. *Resource Allocation in Agricultural Research*. Minneapolis: University of Minnesota Press, 1971.

Foster, Edward. "The Treatment of Rents in Cost-Benefit Analysis." Center for Economic Research, Dep. Econ. Disc. Pap. No. 79-106, Jan. 1979a. University of Minnesota.

———. "Competitively Awarded Federal Grants." Mimeographed. Dep. Econ., University of Minnesota, Jan. 1979b.

Gustafson, T. "The Controversy over Peer Review." *Science* 190(1975):1060–66.

Guttman, Joel M. "Interest Groups and the Demand for Agricultural Research." *J. Polit. Econ.* 86(1978): 476–84.

Hadwiger, Don. "Changes in Political Support for Agriculture." *Food and Agriculture Policy Issues*, ed. Luther Pickrel, pp. 43–49. University of Minnesota Agr. Extens. Serv. Spec. Rep. 71, 1978.

Hayami, Yujiro, and Vernon W. Ruttan. *Agricultural Development: An International Perspective*. Baltimore, Md.: Johns Hopkins University Press, 1971.

Heady, Earl O. "Public Purpose in Agricultural Research and Education." *J. Farm Econ.* 43(1961):566–81.

———. "An Alternative View of State Expenditures." *J. Farm Econ.* 44(1962):454–61.

Huffman, Wallace E., and John A. Miranowski. "An Analysis of State Expenditures on Experiment Station Research." Mimeographed. Dep. Econ., Iowa State University, Mar. 1978.

Kaldor, Donald R. "Social Returns to Research and the Objectives of Public Research." *Resource Allocation in Agricultural Research*, ed. Walter L. Fishel, pp. 62–79. Minneapolis: University of Minnesota Press, 1971.

———. "Some Issues in Specifying an Objective Function for Evaluating Public Agricultural Research." Mimeographed. Dep. Econ., Iowa State University, 1978.

Keyfitz, Nathan. "The Impending Crisis in American Graduate Schools." *The Public Interest* 52(Summer 1978):85–97.

Leopold, A. Carl. "The Burden of Competitive Grants." *Science*, no. 203 (1979), p. 607.

Mansfield, Edwin et al. *The Production and Application of New Industrial Technology*. New York: W.W. Norton & Co., 1977.

Mayer, Andre, and Joan Mayer. "Agriculture, the Island Empire." *Daedalus*, no. 103 (Winter 1974), pp. 83–96.

Meier, Kenneth J. "The Agricultural Research Service and Its Clientele: The Politics of Food Research." Paper presented at the 1977 annual meeting of the Southwestern Political Science Association, Dallas, 1977.

Mueller, Willard F. "The Origins of Basic Inventions Underlying duPont's Major Product and Process Innovations, 1920–1950." *The Rate and Direction of Inventive Activity*, ed. Richard R. Nelson, pp. 323–53. Princeton, N.J.: Princeton University Press, 1962.

National Research Council. *Report of the Committee on Research Advisory to the USDA*. Springfield, Va.: National Tech. Infor. Serv., 1973.

———. *World Food and Nutrition Study: The Potential Contributions of Research*. Washington, D.C.: National Academy of Sciences, 1977.

Niskanen, William A. "Bureaucrats and Politicians." *J. Law and Econ.* 18(1975):617–44.

Paarlberg, Don. "A New Agenda for Agriculture." *Policy Stud. J.* 6(1978):504–06.

Peterson, Willis L. "The Allocation of Research, Teaching, and Extension Personnel in U.S. Colleges of Agriculture." *Amer. J. Agr. Econ.* 51(1969):41–55.

———. "Publication Productivities of U.S. Economics Department Graduates." Staff Paper P73-27, Dep. Agr. and Applied Econ., University of Minnesota, Oct. 1973.

Puterbaugh, Horace L. "An Application of PPB in the Agricultural Research Service." *Resource Allocation in Agricultural Research*, ed. Walter Fishel, pp. 316–25. Minneapolis: University of Minnesota Press, 1971.

Ruttan, Vernon W. *Bureaucratic Productivity: The Case of Agricultural Research*. Dep. Agr. and Applied Econ. Staff Pap. P78-16, University of Minnesota, Nov. 1978.

Shumway, C. Richard. "Models and Methods Used to Allocate Resources in Agricultural Research: A Critical Review." *Resource Allocation and Productivity in National and International Agricultural Research*, ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 436–57. Minneapolis: University of Minnesota Press, 1977.

Sprague, George F., ed. *Corn and Corn Improvement*. New York: Academic Press, 1955.

Stakman, E. C., Richard Bradfield, and Paul C. Mangelsdorf. *Campaigns Against Hunger*. Cambridge, Mass.: Harvard University Press, 1967.

Stein, Bernard R. "Public Accountability and the Project Grant Mechanism." *Res. Pol.* 2(1973):2–16.

Strobel, Gary A. "A New Grants Program in Agriculture." *Science*, no. 199 (1978), p. 935.

Ulbricht, Tilo L. V. "Contract Agricultural Research and Its Effect on Management." *Resource Allocation and Productivity in National and International Agricultural Research*, ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 381–93. Minneapolis: University of Minnesota Press, 1977.

U.S. Department of Agriculture, Cooperative State Research Service. *Funds for Research at State Agricultural Experiment Stations and Other Cooperating Institutions*. Washington, D.C.: CSAS 15-11, Jan. 1976.

U.S. Department of Agriculture, Science and Education Administration. "Competitive Grants for Basic Research: Plant Biology and Human Nutrition." *Federal Register*, vol. no. 43, 7 March 1978a, pp. 9432–40.

———. *To Administrators of Cooperating State Research Units*. Washington, D.C.: Exp. Sta. Letter 1455, 26 May 1978b.

———. To *Directors of State Research in Agriculture and Forestry*. Exp. Sta. Letter 1438, 27 Jan. 1978c.

Mr. FUQUA. Thank you very much, Dr. Huston.

Let me ask all three of you, what type of program do you have in your research that funds the replacement of facilities and instrumentation in these research facilities, or is there a systematic approach? Now I'm really thinking of the laboratories in the universities or Experiment Stations and so forth.

Dr. KINNEY. Mr. Chairman, let me respond first, and I can respond only for the ARS laboratories, but we use a part of our support funds to do that on a continuing basis. We haven't always in the past done as good a job as we should do because we were a dispersed organization, but now that we have a centralized management of ARS facilities, program, and so forth, we have begun a program that is taking inventory of all of our facilities and equipment, and we are giving specific attention to updating all of our equipment.

We are in amazingly good shape, the survey is showing, but we are going to get on a basis where we are going to take a percentage of these support funds each year and look at the needs, not on a local basis but on a national basis, so that we will be replacing things like electron microscopes and so forth.

Mr. FUQUA. How much are you talking about, percentage?

Dr. KINNEY. We're talking about now 3 to 4 percent of our base funds, and that doesn't seem very much but when you're talking about a half a billion dollar budget, it amounts to quite a bit. In addition, we do have $12 to $14 million of repair and maintenance funds each year, the funds that have regularly gone from program into this sort of thing, so we are very much concerned about it but we are going to solve it in-house. We are not looking for any special appropriations.

Mr. FUQUA. Dr. Jordan.

Dr. JORDAN. Mr. Chairman, this is perhaps one of the most important topics for the land-grant and university-based research component for agriculture that we could address, and the philosophy behind the bill that you have authored and that which was submitted by the administration in the farm bill are exactly parallel, and recognize the significance of this. The expectations are that in the university system we are in the process now of trying to ascertain very accurately what it is in agriculture, but it will run somewhere in the vicinity of 15 percent of the total budget from the Federal Government to the States.

What happens is that what we are hunting for firm data on that is to find out from the individual stations the buildings and facilities that they have already approved by the State screening system, so they are not "wish lists," and then if they want to have another category that says, "Well, they have been approved on the campus level but not by the State," that gives us something more to take a look at, but very hard data in that regard, so the principle is very sound.

Mr. FUQUA. Dr. Huston.

Dr. HUSTON. At the State level there is considerable variation but I think I can generalize in this fashion: that buildings and fixed equipment normally are dealt with by the State legislature as

a separate request from the universities. The process within the university with regard—and this is where the Experiment Stations are more tightly tied to the university than they are in many other ways—in a general sort of a way, the priorities with regard to building are established by a campus committee which reports to a vice president or a president or some sort of a group of this sort and, having served on one of those, I can tell you that what happens is, you develop a list. The list is very long. You inch your way up year by year by year, trying to get there, and you may as a part of the committee get to the top of the list, only to find that when the president goes to the legislature, you are back down in third place. There is a little slippage involved in the process, if I may say so. But, nonetheless, we are part of the university community so in that context we operate that way.

Now we have had in many States, when the situation got desperate enough, we have had some of the agricultural people in the State go directly to the legislature and say, "We must have that building," and they have done it that way.

With regard to movable equipment, there are two features of this. We have the capacity as a unit to provide equipment in competition with other resources, and in this we rely on our department heads and scientists and say: "Well, now, you've got the choice. Here are the dollars. You go ahead and tell us what you want most." Up until very recently their choice was heavily on faculty because of the specialization and the need for the faculty, but increasingly now as the opportunity presents itself—many of our scientists are beginning to retire—they are beginning to shift over and invest more heavily in equipment. The start-up costs as you bring these young scientists in are much larger in terms of new kinds of equipment than they were before. In some of our fields—for example, in some of our crop production fields, where tractors and fields and harvesting equipment were normal parts of their experimental stuff—we have that on hand, but it is some of this new computer, biological, biotechnology equipment that is particularly difficult.

Mr. FUQUA. Yes, Dr. Kinney.

Dr. KINNEY. We find that scientists and research leaders very often are not much different than farmers. When times are tough, they mind the farm. They don't paint the building; they don't replace the equipment. So that is one of the reasons that we ofttimes find ourselves in difficult circumstances.

One of the criteria that we have established and we are adhering to in ARS, because we do monitor research programs annually and approve them, one of the criteria for approving a research project is, "Do they have the equipment available to do the research?" If they don't have the equipment, then it reflects bad management on the part of the research manager and the project is not approved, so it's a strong motivating force.

Mr. FUQUA. Dr. Kinney, what percentage of your work is done in-house or at Federal facilities—I'm thinking of something like Beltsville—versus university research?

Dr. KINNEY. About 30 percent of our research projects are conducted at or on land-grant university campuses, cooperative with

them, and the number of scientists ranges all the way from 1 or 2 up to 35 or 40 on a university campus.

Dr. HUSTON. Let me give you an answer from the State side. There are, nearly as we can tell, about 600 scientist-years from the Federal agencies on our State Experiment Station campuses. We don't normally talk about the State resources that go into Federal research but I made an estimate several years ago and came out with somewhere between $30 to $40 million that was easily accounted for without taking into consideration land, farms, buildings, livestock, and things of this sort that it's terribly hard to put a value on.

Mr. FUQUA. Well, what percentage is the difference between the formula grants under the Morrill Act and some of the others that have been enumerated, versus Competitive Grants that were referred to? How does that break down?

Dr. JORDAN. The relative size of projects?

Mr. FUQUA. No, I'm talking about the percentage of your budget that would be——

Dr. JORDAN. Of our budget? $162 million in the last fiscal year on the Hatch Act, $23 million in the Evans-Allen, and $13.1 million in forestry research, so just about $200 million, and the Competitive Grants Program is $54 million. That is a separate category, and then also the special grants is another $34 million.

Mr. FUQUA. Dr. Jordan, you mentioned a relationship that you had with NSF and NIH and so forth. There seems to be a gradual accumulation of joint boards and advisory panels and so forth, more than there are in some of the other Federal agencies that are involved in that type of a program. Is that a healthy thing or has it gone too far toward advisory groups, enough that the structure in the future, would you recommend it be reduced or changed any?

Dr. JORDAN. I think the issue that is legitimate here is that the quality of science has to be measured by peer scientists, and once you have done that, the management effort has to be done separately from that, so in the Experiment Station system that is pretty well separated into two categories. There is an awful lot of advice input and maybe at a given station level, Dr. Huston, there are so many advisors from various commodity groups and what not that it becomes a burden but, in terms of the assurance of quality, we try to constrain that to a reasonable number of scientists reviewing it. The average number of people that go out on a site visit for CSRS—and this will be, now, a review of a program every 4 to 6 years, a thorough review of program at each site—there will be about 4 to 5 people on that review team. It depends on the complexity of the discipline being reviewed, but the minimum number needed to assure quality and yet at the same time not to get out of hand.

Mr. FUQUA. Dr. Kinney, do you wish to comment on that?

Dr. KINNEY. Yes, I do. I guess maybe as times get more and more difficult—and by "times" I mean the budgeting, funding for all of the things that we should do or would like to do—it seems we get more and more advice, because the users of our product become concerned, so we have had a proliferation in my opinion of many, many advisory groups. I attended a Brookings Institution meeting yesterday and listened for most of the day to a lot of consultants

who told us what ought to be done to solve the farm crisis problem, and so forth and so on, said what the Congress should do, what the Department should do, and they didn't tell me anything I didn't know when I walked in there. It seems to me we should spend more time talking about strategy. We know what to do. The thing is, how do we do it? So yes, NSF and NIH, I think their groups are good because generally they are giving scientific advice and not complaining about all the things we're not doing that we should do.

Mr. FUQUA. Well, we have in the Department of Energy, we have the ERAB, the Energy Research Advisory Board made up of private citizens or nonagency people, and NASA has that in their space science area, an outside distinguished panel that says, "These are the categories that we think need high priority." They are not necessarily telling you what to fund or not to fund but these are broad categories, and then you take that advice and try to apply it in your own basic need. I just wonder sometimes if Congress is at fault, too, in mandating some of these, and I was just wondering if the structure was such that it might be an inhibitor in the future.

That was more of a comment, rather than a question, but——

Dr. KINNEY. It takes a lot of time. We take a lot of time, and I have looked at research priorities for many, many different groups, including industry groups and others. The question I always ask is, What have you left out? We get a list of priorities and it includes everything, so I don't know what good the list is. When we set priorities, we talk about what we're going to not do and what we're going to do.

Mr. FUQUA. Yes.

Dr. HUSTON. I would like to put a little different perspective in from the State end. We probably, in comparison with Federal groups, are much more heavily involved in these sort of interrelationships. While they sometimes prove burdensome in terms of time demands, we feel that they keep our scientists and our administrators looking very closely and knowledgeable about the problems as they emerge, and while the seat gets a little hot sometimes, nonetheless you've got your friends there that are interested in what you're doing. They are criticizing you when they think you're wrong, and I think it helps move the system along very effectively.

Mr. FUQUA. All right. Dr. Kinney, I was looking in your statement. I think you said something about that you were developing a long-range plan for agricultural research for 30 or 40 years. In developing that strategy, did you come up with examples of new methods of funding or different management techniques or even other approaches and so forth in that study?

Dr. KINNEY. No, we didn't. This program plan, of which I think a copy has been provided to you, simply outlines what we see as the technologies, the science that is going to be necessary in the next 20 to 50 years, and it outlines the role that we see ARS playing. We are not talking about the total system, only ARS, and a number of groups were very disturbed when we came out with this plan, simply because they didn't see their needs in there. It was simply because we didn't see satisfying their total needs as a mission of ARS, so this is strictly a plan that establishes the science, the approach, and the policies. Perhaps the most important part of

that document is at the end, where we establish six policies for ARS that say, This is how we are going to operate.

Mr. FUQUA. What percentage, or maybe some ballpark figure, in the allocation of funding that goes to individual investigators versus to an institution, is there a breakdown of that?

Dr. HUSTON. Yes.

Mr. FUQUA. Should it be more one way than the other, or——

Dr. JORDAN. In the case of the Department of Agriculture and the Cooperative State Research Service, we have a breakout of about 75 percent that's identified for institutional funding, perhaps a little larger than that, and the remainder of it on an individual basis, which would include the SBIR program.

Mr. FUQUA. Do you think that's an adequate balance?

Dr. JORDAN. We think that the base funding is exceedingly important, because it's on that base that you build the spikes of excellence, if I may indicate that, and use the specific directed funding and individual funded programs to fit into that. What we think is needed is a more—a larger volume of money in the individualized Competitive Grants Program, but not at the expense of the base program. That would be penny-wise and pound-foolish, to erode that foundation.

Mr. FUQUA. Dr. Huston.

Dr. HUSTON. Let me draw a contrast in our Experiment Stations. We have competitive programs in the Department of Agriculture which are agriculturally oriented. There are also similar programs at NIH and NSF—NSF largely oriented toward the particular science, NIH largely toward the medical issues. We draw money in the Experiment Stations from all three sources. As you compare them, the nice thing about the Competitive Grants in agriculture is that they keep your scientists who get the grants working in agricultural problems. When you go to NIH, the flavor is obviously human medicine. Now in our animal work that isn't so bad. When you go to NSF, the flavor is largely science-oriented, and there there can be a drifting away from the specific interest, for example, in wheat or corn or grapefruit or something, onto something more esoteric but scientifically important, and so we think that there is a difference in the kinds of grants and the kinds of agencies that our award grants, in terms of maintaining a stable program.

Mr. FUQUA. Do you think that NIH and NSF ought to use the concept of base funding or formula funding for its universities?

Dr. JORDAN. If you were to talk to them, Mr. Chairman, they view this as one of the weaknesses in their program. that there is an inadequate amount of institutional funding. The National Science Foundation at one time had such a program. It has washed away in the meantime, and the NIH has a very modest one at the moment, the biomedical sciences——

Mr. FUQUA. But it's not a formula, though. It's more of a block grant.

Dr. JORDAN. That's right. It's a biomedical sciences support grant program, and it's driven by how much other biomedical science, NIH-funded biomedical science, is carried out at your institution.

We have some formulas that are somewhat hybrids in that regard. In particular, the program for funding animal health and disease takes into account the size and scope of the animal indus-

try in the State. It takes into account the size and scope of agriculture in that State, and it also takes into account the size and scope of your capacity to perform biomedically-related research, so all of those characteristics are put together and it works fairly well.

Mr. FUQUA. Mr. Brown.

Mr. BROWN. Thank you very much, Mr. Chairman.

I think all of you gentlemen recognize that this task force is looking at the overall position of science, federally-supported science, and we're trying to determine the strengths and the weaknesses of each of the different methods that the Federal Government uses. The chairman's last question is indicative of that search. We find increasing, not complaint exactly, but an awareness of the considerable amount of time spent by scientists in the preparation of grant requests, for example, which is a defect of the Competitive Grant system, and sometimes these scientists look longingly at the formula system as a substitute for that, or longer period grants at least, and we need to balance these factors.

You have all been enthusiastic supporters of the ag research system, and I am also, but in looking at that system we want to also see what its weaknesses might be. You know overall this system, which is the best research system in the world—as you pointed out, Dr. Jordan, and I'm sure you all feel—has produced a very sick agriculture. Now that may not be cause and effect, but we need to find out why we have that situation.

Something similar is true in our biomedical and health research. We have the best system in the world. We have been the leaders in the world, and yet we have the most expensive health care system and one which is not the world leader in terms of infant mortality and longevity and some other factors of that sort. We need, from the standpoint of a committee looking at science policy, to understand why we don't have these corresponding beneficial effects from what we perceive to be excellent systems of science support, and that's a very difficult question.

Dr. Huston, you said one thing that caught my eye or ear, and I'm sure Mr. Fuqua's, that the percentages of Hatch Act funding in California and Florida are amongst the lowest in the Nation. Would you like to explain just why that is the case?

Dr. HUSTON. They are not among the lowest. They are among the least of the share of the budget. For example, in California, as I recall the number, Mr. Brown, around 4 or 5 percent of the total California budget comes from Federal funds, from Hatch funds. The same is true in the Florida station.

Now in States there is a little bit of what you were hitting at, that California and Florida, with as large agriculture as they have, don't get as much of the Federal funds as some of the other States that have less, but the formula is a formula based on farmers and people in agriculture, not on the output. I must admit candidly that those of us in the Midwest wouldn't mind one bit if the formula were shifted over to a sales basis because we, like Florida and California, would gain considerably from it.

On the other hand, as we look at our brethren in the Mountain States, and those up in the Northeast and some of the Southern States, the Hatch funds attract State resources there, and in terms

of the total system the formula that provides some for even the least has some distinct benefits at the system level.

Mr. BROWN. This formula was handed down by Moses, was it? [Laughter.]

Dr. HUSTON. No, or it was almost, yes. May I speak to that? I was on a committee in 1971, as a fresh administrator, asked to examine this formula, and I was imbued with the notion it ought to be related to cash sales in agriculture, and I was trounced within 10 minutes of the discussion. I simply couldn't construct a majority.

Mr. BROWN. Well, I'm sure you gentlemen all know that we tried to alter the formula this year, and we ran into some of those objections from some of the States which benefit from the present formula. As I understand the situation now, Dr. Kinney, you are going to do a 1-year review, or the Department is, of alternative formula systems that we could use. I think that language is in the farm bill, if we ever get it passed.

Well, that was the alternative, a very common alternative that we use: If you can't get something through, study it for a year. I hope, however, that if that language does pass, that the Department of Agriculture will propose some reasonable alternatives that would at least slightly increase the weight of the agricultural sales. Nobody is asking that we drastically alter the formula. It has never been drastically altered. Every change has merely been added on top of the existing formula, so that it produces a very slight modification.

Dr. KINNEY. Congressman Brown, Loretta Owens just informed me that Dr. Greenwood, the Administrator of the Extension Service, will be heading the study of that.

Mr. BROWN. Yes. Well, we'll look forward to seeing some results from that.

We are undoubtedly trying to finish before——

Mr. FUQUA. Right. I apologize for asking so many questions.

Mr. BROWN. Oh, no. Your questions were excellent, Mr. Chairman.

I had a comment. I have a number of questions but won't be able to go into them. I wanted to make a comment. Dr. Jordan, you said something about the fact that no nation has ever built such a knowledge-based system with such high-quality science at such low-level cost, and I concur with that. I think you also pointed out that most of our agricultural scientists come out of that system. I'm sure you are aware that a good share of the agricultural research in the Third World also come out of that same system, and that needs to be added to the values that this system has produced. I think it's a world asset, not just a U.S. asset.

Getting back to the point I originally made—Why do we have a sick agriculture with such a good system?—what has happened to the policy sciences in agriculture over the last 20, 25 years—to agricultural economics, to agricultural sociology, to some of the other sciences which might look at the overall conditions of agriculture, and not just those factors which increase its productivity and happen to decrease its profitability at the same time? What has happened in that area?

Dr. JORDAN. There are—this is probably the number one topic of interest in the agricultural research community of the university

because of what appear to be no answers coming out. Part of that is that the disciplines themselves have found that the complexity of the situation makes it difficult to predict, and they say that's not a good enough answer.

The second one I think is more important and that is, because of the complexity the disciplines have found it very difficult to define and state clearly the researchable question. So as a part of the planning effort in the Experiment Station system, a major effort has been put forth and some planning money provided by CSRS to the Ag Economics Association and the World Sociology Association and so on to do exactly that, with the idea that you have got to have a clear statement of the researchable questions, know what it is you can find the answers to, and relate those to the problem areas, and perhaps that will be helpful.

Mr. BROWN. I suppose part of the problem is also that this is where agricultural problems intersect with the rest of society——

Dr. JORDAN. That's absolutely correct.

Mr. BROWN. Run up against political ideology and other things.

Dr. JORDAN. That's right, and so if the Europeans play on a different policy base than we do, it doesn't make really for an open market, does it?

Dr. HUSTON. Let me comment just quickly from some experience that we had in the Midwest. We had, at one of our institutions, policy people who developed what they perceived as an appropriate approach. When it hit the State in the published form, the political multiplicity of views—if I can say it that way—emerged, and that policy unit was discontinued in the university, so it is a very sensitive issue. We have talked some in the Midwest, where we have traditionally some very keen policy activities, about whether there is a way one might insulate these. You need to have them separate from the Federal Government so they won't take the Federal line, but at the same time you maybe have to have them separate from the State government so they won't get entangled in State affairs.

Mr. BROWN. Gentlemen, I have a lot more questions but we better bring an end to this at this time. I will defer, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Brown, and I want to thank all of you for joining us this morning. It has been very helpful and, as Mr. Brown pointed out, what has been done in USDA over the years has been certainly an excellent example of what Government can do in trying to fund some of the seed research—not "seed" in the normal context, but much of the very important research—and it has proven that if we hadn't done such a good job, we wouldn't have such a problem over on the floor right now trying to pass a farm bill. [Laughter.]

Thank you very much.

[Whereupon, at 12:10 p.m., the task force recessed, to reconvene on Friday, October 4, at 9:30 a.m.]

[Answers to questions asked of Dr. Kinney, Dr. Jordan, and Dr. Huston follow:]

United States Department of Agriculture
Agricultural Research Service
Office of the Administrator
Washington, D.C. 20250

RECEIVED
NOV [illegible] 1985
COMMITTEE ON SCIENCE AND TECHNOLOGY

October 31, 1985

Honorable Don Fuqua
Chairman, Committee on
Science and Technology
House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

Pursuant to your request of October 11, 1985, there is enclosed a packet of information which responds to the written questions submitted to supplement the record of the October 3, 1985, hearing of the Science Policy Task Force.

As always, Mr. Chairman, we appreciate the interest of your Committee in our programs and I appreciated the opportunity to meet with the Task Force.

Sincerely,

T. B. Kinney, Jr.

T. B. KINNEY, JR.
Administrator

Enclosure

1. How do Agricultural Research Service programs compare with the science programs of the science agencies in their effects on science and on the universities?

Dr. Kinney. They are similar in that ARS research programs contribute significantly to the scientific knowledge base of the broad areas of biological and physical science. Most of the approaches to solving problems and finding research solutions in ARS are similar to scientific research conducted by other research agencies in the Federal government. However, research conducted by ARS is mission-oriented and focused on solving specific national problems for agriculture, whereas many of the science projects in universities are focused on answering biological and physical questions rather than development of technology for the solution of a specific problem for a user.

2. Acting on the priorities developed in agricultural research, how do you handle the phasing out of research activities which no longer have any priority attached to them?

Dr. Kinney. Projects in ARS have a 3- to 5-year duration. As these projects are completed, an assessment is made by the scientists and managers in ARS on whether to continue the work in the same problem area. If priorities change, resources are normally redirected at, or near, the end of the project completion date. If a major change is made in the area of work, the user group for that research is contacted prior to the redirection of the work. Although the user group may not concur in the redirection, particularly if the new research is in a different commodity or area of interest to the user group, the reasons for the redirection are explained to the user group. For the most part, industry and user group priorities are the reasons for the redirection of the research. Thus, there is generally concurrence for the redirection of research activities.

3. Agricultural research has always had to focus some fraction on problems arising suddenly in the actual practice of agriculture, or in response to what a recent report called "nature based agricultural emergencies." How large a percentage of all agricultural research falls in this category, and what is the longer term trend in such research?

Dr. Kinney. The percentage of resources in ARS required for solution of emergency problems is relatively small. I would say it accounts for less than 5 percent, within a given fiscal year. Although ARS has given much attention the last few years to focusing research to meet the needs of USDA action agencies and other user groups, the projection of resources required to meet emergency needs does not appear to have changed over the past 10 years.

4. In today's environment, how successful are the several components of the agricultural research system in attracting each year a number of the younger researchers into agricultural research work? In the coming decade, how do you see the prospects for recruiting good researchers into agricultural research?

Dr. Kinney. We think we have been reasonably successful in attracting and retaining top, young scientists to ARS in recent years. ARS has initiated a postdoctoral program which has resulted in hiring young, highly selective investigators to work with our best and leading scientists. Already, some of these young scientists have been hired permanently by ARS and others have returned to the university or entered the private sector to work on agriculturally related problems.

During the past 4 years, there has been a particularly intense recognition of the challenging agricultural problems and a recognition of the needs to train scientists in areas critical to agriculture. University administrators and faculty are responding by encouraging quality graduate students to work on the difficult but exciting biosagricultural problems. One of the motivating factors has been the infusion of dollars through the USDA competitive grants program and another is the concentrated effort of the National Science Foundation to focus on increased funding support for the plant sciences. In the coming decade, additional support will be needed to strengthen graduate student programs in the biosciences, especially the animal area, if a continuous supply of well-trained agricultural researchers is to be assured.

5. You noted that the Agricultural Research Service has recently developed a plan covering the research opportunities for the next 20 to 50 years. We have often heard from other scientific institutions that such long-range planning for science is almost impossible because of the uncertainty about which discoveries will be made in science. How are you able to do long-range planning for agricultural research?

Dr. Kinney. In the ARS Program Plan, we attempted to project the research needs and opportunities for the long-term, 20-plus years. In addition to this Program Plan, however, we developed a six-year Implementation Plan. This six-year plan is used to guide our research and budget process on a year-by-year basis. We agree with the observation of other scientific institutions and agencies that such long-term planning for science is, at best, unsure. However, much of today's technology was developed from scientific research initiated about 20 years ago. Thus, we think it is imperative that we have a long-range plan as well as a six-year plan for operating purposes. We fully recognize that the planning process must be continuous and even a six-year plan must be adjusted annually in light of new research findings in agriculture and other fields of science and to changing needs in agriculture. Most of the national problems in agriculture do not change within a decade, but scientific approaches to solving these problems must be adjusted as new information is available.

6. In other areas where science provides a strong input to technological innovation, it has often been said that the agricultural system, including the close connection between research, extension and education could serve as a model. Yet the repeated attempts, for example, by the Department of Commerce 20 years ago and more recently by some of the States, to apply the agriculture model to other industries have not had much success. Have you any thoughts why that is so?

Dr. Kinney. Most assessments of the effectiveness of the agricultural system are based on the fact that U.S. agriculture has been able to produce an adequate, wholesome, and safe food supply for the American public. Agriculture has essentially had only one goal: the production of an abundant supply of food and fiber. Perhaps the goal of the agricultural system has been more specific than that of the other industries. However, at the present time there is widespread concern that the "agricultural system" may not be adequate to meet the evolving needs of agriculture.

7. Is the present structure for the management of agricultural research going to remain the same 25 years from now? Or, to put it another way, if you could write a new Act to replace the Morrill, Hatch, Evans-Allen, McIntire-Stennis, and other Acts now governing the system to take effect in year 2000, how would you structure the agricultural research system as you think about the long-range future needs and the less useful parts of the present system?

Dr. Kinney. No, I do not think the management of agricultural research is going to remain the same over the next 25 years. In agricultural research, we have seen a substantial change in the past 5 years in the relationships of public and private sector research and development. We have seen a much greater increase by the private sector in projecting the needs to research managers and scientists in the public sector. I think it is imperative that the linkage between public-supported agricultural research and the private sector continues to increase. It is my opinion that the management of agricultural research will continue to change to meet this and other needs over the next two decades. ARS was reorganized two years ago to assure that we would be responsive to those changes that are taking place.

If I could write a new Act to replace those existing for agricultural research, I do not believe I would make substantial changes. The present system, on net, has been highly effective; and I see no reason it should not continue to remain highly effective. There have been instances where parties involved, including managers of agricultural research, have not utilized the flexibilities within the system to adequately meet the needs for agriculture. The problems, in my opinion, have to do more with individuals or groups than they do with constraints of the existing Acts.

8. As you look over the total Federal program of support for scientific research, do you see any aspects of the agricultural research system, whether it is in management, project selection, planning, funding mechanisms, or the dissemination and use of research results, that could be applied to research support in other areas other than USDA's research programs?

Dr. Kinney. Although ARS research is mission-oriented, science for agriculture has a great deal in common so far as management, program selection, planning, funding, and research approaches with other Federal agencies. This is true for several reasons. Scientists in a given disciplinary field use the same techniques, methodology, and scientific approaches to test a hypothesis or focus on a problem regardless of species. Scientists and research managers in most fields of science attend many of the same research meetings and have a relatively high level of interaction with peers without regard to their organization affiliations. A significant percentage of scientists and research managers in ARS have worked previously in other Federal research agencies and State and private universities. There are many scientists and research managers in other Federal research agencies who were formerly in the Agricultural Research Service and/or State Agricultural Experiment Stations.

9. In developing the long-range plan for agricultural research, did you come up with any recommendations apart from the subject matter itself, such as for example, emphases on new methods of funding, different management approaches, and so forth?

Dr. Kinney. In developing our Program Plan and the 6-year Implementation Plan, we first assessed the mission and role of the Agricultural Research Service. We did not come up with new methods of funding, but rather placed emphasis on the need to more clearly define the established national problems that ARS should address. As part of this process, the management was changed to give more focus to national programs and less focus to State and local research needs. A system was also developed to realistically establish research priorities based on user needs.

10. In a recent study by Dr. Lipman-Bluman, it was found that agricultural research, perhaps more than other areas of government-supported research, is subject to political influences. Specifically, such things as priority setting, laboratory closings or staffing are addressed by the Committees of the Congress. Without necessarily getting into specifics, would you comment in more general, philosophical terms on the advantages and disadvantages to a research program of such close interaction with the political system?

Dr. Kinney. The interest of national commodity and other user groups is reflected by actions of Congressional committees on ARS research programs. This interest by Congressional committees, on net, is very positive. The negative impacts on research programs as referred to in your reference to the Lipman-Bluman report are not a problem for ARS. For the most part, this level of interest in use of tax dollars ensures that ARS programs will be focused on relevant needs of the users and that technology transfer will be fast. The only constraints on management of Agricultural Research Service programs by Congress and by user groups relate to location closures and to shifting of funds from one commodity or user group to another. Congress will occasionally object to our attempts to consolidate programs by closing unneeded facilities. Overall, I think that Congressional and user group interest in ARS activities is a plus.

United States Department of Agriculture | Cooperative State Research Service | Office of the Administrator | Washington, D.C. 20250

NOV 0 1 1985

Honorable Don Fuqua
U.S. House of Representatives
Chairman, Committee on Science
and Technology
Washington, DC 20515

Dear Mr. Chairman:

In response to your letter of October 11, 1985, I have prepared the enclosed statements.

I appreciated having the opportunity to appear before the Task Force and look forward to further interactions as you continue your assessments.

Sincerely,

JOHN PATRICK JORDAN
Administrator

Enclosures

1. How do Cooperative State Research programs compare with the science programs of the science agencies in their effects on science and on the universities?

Dr. Jordan. The Cooperative State Research Service is a science agency and its programs, like those of many other science agencies, are carried out primarily through universities. In this regard, CSRS programs have had effects similar to those of other Federal programs that support individual project leaders, but do so in the field of agriculture. They differ in one major respect. Specifically, the 50 State legislatures have at least matched the CSRS funding, and many have matched $3 or more for each CSRS Federal dollar provided.

Many important advances can be attributed to projects supported by CSRS funds. CSRS programs have also brought an additional dimension to research; that of a national, coordinated program to bring together researchers at many institutions to address particular problems. By encouraging this kind of networking, expertise at different institutions has been brought together to address problems in ways that would be impossible for individual institutions. CSRS is currently providing over $35 million in funding to programs where two or more State agricultural universities are working together on common problems.

2. Acting on the priorities developed in agricultural research, how do you handle the phasing out of research activities which no longer have any priority attached to them?

Dr. Jordan. Research projects are approved for no more than five years. Base or formula-funded research projects are reviewed at the end of the period and are either revised or terminated, based on the results of the review. If revised, they are subject to a new peer review and must receive favorable recommendations before they are approved for continuation. Special Grant projects are not continued beyond a maximum of five years.

3. Agricultural research has always had to focus some fraction on problems arising suddenly in the actual practice of agriculture, or in response to what a recent report called "nature based agricultural emergencies". How large a percentage of all agricultural research falls in this category, and what is the longer term trend in such research?

Dr. Jordan. Emergencies arise from time to time in the agriculture sector, and require a short-term shift of emphasis in research effort. However, with the strong base program of research, and with emphasis on fundamental research, the system is capable of responding quickly to such emergencies. It is estimated that only about 5% of the research effort falls in the emergency category and the percentage is not expected to change much in the long-term. As more basic research is done, it is much easier to respond to emergencies.

4. In today's environment, how successful are the several components of the agricultural research system in attracting each year a number of the younger researchers into agricultural research work? In the coming decade, how do you see the prospects for recruiting good researchers into agricultural research?

Dr. Jordan. Currently, there is growing evidence of deficits of college-educated agricultural scientists, educators, and other professionals in both the public and private sectors. In 1980 our data indicated that demand exceeded supply in several fields of study including: Agricultural Engineering, Food Science, Plant and Animal Molecular Biology and several others. We believe that unless these trends can be reversed, they will impede future U. S. agricultural efficiencies. Between 1977 and 1983, baccalaureate enrollments in agriculture at our Land-Grant Universities declined approximately 30 percent. During this same time period, graduate enrollments diminished by a factor of 5 percent. At the doctoral level, over 32,000 degrees are being awarded annually in the U.S. Only about 1,000 of these are in agriculture and natural resources. And, of these 1,000, approximately 32 percent are earned by foreign students who return to their native country subsequent to graduation. The residual domestic supply of Ph.D. graduates amounts to only some 680 annually available to the U.S. labor force--approximately 14 per State. Projections through the mid-1990's suggest a continuation of these trends.

5. In other areas where science provides a strong input to technological innovation, it has often been said that the agricultural system, including the close connection between research, extension and education could serve as a model. Yet the repeated attempts, for example by the Department of Commerce 20 years ago and more recently by some of the States, to apply the agriculture model to other industries have not had much success. Have you any thoughts why that is so?

Dr. Jordan. I expect that some of the answer relates to the timing with which the agricultural programs were initiated. The Land-Grant Universities were established early in the development of scientific agriculture and they served as a logical base from which to build research and extension programs at a later date. With this focal point established early in the country's history, as agriculture and its infrastructure developed it was logical to build around the support systems of the Land-Grant Universities and their programs, in research, extension and education. In the case of other industries the opportunities to establish similar programs in the same time frame are no longer possible. Another factor may be vested interests that do not see that it is to their best advantage to establish such a system for certain industries.

6. Is the present structure for the management of agricultural research going to remain the same 25 years from now? Or, to put it another way, if you could write a new act to replace the Morrill, Hatch, Evans-Allen, McIntire-Stennis, and other Acts now governing the system to take effect in year 2000, how would you structure the agricultural research system as you think about the long-range future needs and the less useful parts of the present system.

Dr. Jordan. This is always an interesting kind of a question to consider. The various legislative authorities and management structures for agricultural research have evolved over a period of many years. Programs and relationships have developed in a stepwise manner into an effective system that is providing high quality information to agriculture. The Hatch, Evans-Allen, and McIntire-Stennis Acts all called on the States to designate universities and name directors to take responsibility for the programs. The States themselves are much more than matching this Federal investment. This management approach has led to the State Agricultural Experiment Station system that is decentralized, but tied together in a network that responds to national needs as well as State and local needs. With these base programs in place, it has been possible to capitalize on their capabilities to address special problems through special grant and competitive grant project funding.

Looking to the future, I see a maturing of the Evans-Allen institutions and their becoming fully integrated into the system. Animal health research will be funded through its own acts as is forestry today. Home economics research will become better defined, as will agricultural economics, with clearer statements of researchable questions and will warrant substantially greater funding. Agricultural research will develop closer relationships with other basic science agencies, especially NSF and NIH.

For the State Agricultural Experiment Station system, I anticipate that in the year 2000 the needs of agriculture will be met through types of funding similar to those currently in use. That is, I would want institutional funding to maintain a decentralized infrastructure and base programs for agricultural research. Building on this base and other research capabilities, there would be programs of project grants to address special problems. There also should be training grants to insure adequate trained personnel. One important change I see is a larger proportion of agricultural research funding in competitive grants than now--maybe as much as 50 percent. The reason for this is to more fully use all kinds of talent in all kinds of institutions to address and resolve agricultural issues. A second important change I see is a more orderly approach to providing replacement of equipment and facilities. This will apply to both worn out and obsolete equipment and facilities.

7. As you look over the total Federal program of support for scientific research, do you see any aspects of the agricultural research system, whether it is in management, project selection, planning, funding mechanisms, or the dissemination and use of research results, that could be applied to research support in other areas other than USDA's research programs?

Dr. Jordan. One question that has been receiving considerable attention in recent years is whether or not the present practice of major funding for science going via project grants is the most efficient and effective way to fund research. The amount of time spent in preparing and reviewing proposals is considerable. There also is the question of how to maintain the base of research from which the individual project grant proposals can be prepared. In agriculture the approach of having a portion of the Federal funding made available on an institutional basis, with management provided at the State or university level, has been seen as a good balance in this regard. An advantage of this decentralized management has been the shared responsibility by the principal investigator, the Department Head, the Dean, and other university officials for successful conclusion of projects. To promote high quality research we have imposed peer review requirements to be managed at the university level but, nevertheless, applied to all projects funded with these institutional grants. Decentralized management has been particularly effective in agricultural research where problems vary from one geographic region to another. It has also ensured a base program from which high quality proposals can be developed in response to needs for increased effort on particular programs, as in our competitive grants program. I believe that further use of institutional funding should be considered. Agriculture's Current Research Information System is developing into an effective, easily accessible science information system that can serve as a model for other areas. Finally, a well organized outreach effort like our Cooperative Extension Service is extremely important in getting research results applied by all users.

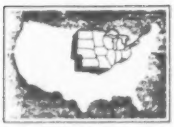
8. In developing the long-range plan for agricultural research, did you come up with any recommendations apart from the subject matter itself, such as for example. Emphases on new methods of funding, different management approaches, and so forth?

Dr. Jordan. Funding for the total research effort put forth by the State Agricultural Experiment Station system comes from several sources. Each source of funds fills a specific niche, but the base funds for the entire system come from the combination of State appropriated funds and formula funds from CSRS. Peaks of excellence and focused productivity can be accomplished by using all other sources of funds. We now see value in base or institutional funding, special grants to areas of special need, competitive grants for national focus using talent in all types of institutions, and training grants to ensure a reservoir of trained, talented people. We are also looking at approaches similar to the McKnight Foundation's program projects, or nested projects, as the organizational base.

9. In a recent study by Dr. Lipman-Bluman, it was found that agricultural research, perhaps more than other areas of government-supported research, is subject to political influences. Specifically, such things as priority setting, laboratory closings or staffing are addressed by the Committees of the Congress. Without necessarily getting into specifics, would you comment in more general, philosophical terms on the advantages and disadvantages to a research program of such close interaction with the political system.

Dr. Jordan. An important advantage to close interactions with a political system is that it provides an opportunity to keep the Congress well informed on the programs and results of the agricultural research system. As long as we have effective programs and a good product to sell, we are in an enviable position of having the ear of the body that ultimately determines the funding level for the program. It also provides for early interactions and dialogue on problems that the Congress may see developing. The primary disadvantage of this close interaction arises when individual interests surface in directives that are not in the best interest of the total system.

If Congressional earmarking begins to direct a major portion of the program (more than about 5%) it could threaten the effectiveness of the system-wide program planning which has considerable citizen input.



NORTH CENTRAL ASSOCIATION
OF AGRICULTURAL EXPERIMENT STATION DIRECTORS

OFFICE OF THE DIRECTOR-AT-LARGE
O.A.R.D.C.
WOOSTER, OHIO 44691-6900
TELEPHONE: (216) 263-3768

November 25, 1985

Honorable Don Fuqua, Chairman
Committee on Science and Technology
U. S. House of Representatives
2321 Rayburn House Office Building
Washington, D. C. 20515

Dear Mr. Fuqua:

Enclosed are my responses to questions for the record of hearings on "Science in the Mission Agencies and Federal Laboratories". Your questions were reviewed with great interest by administrators of State Agricultural Experiment Stations. I received suggestions from Station Administrators of the States of Connecticut, New York, Michigan, North Dakota, Indiana, Georgia, Wyoming, Colorado, Maryland, Mississippi, Minnesota, and from the Directors-at-Large for the Southern, Northeastern, and Western Regions. They were all much impressed with the perceptiveness about and genuine interest in agricultural research.

Sincerely,

Keith Huston

Keith Huston
Director-at-Large

KH:mjw

encl.

cc: Dr. John Holmfeld
Dr. Harlan Watson

RECEIVED
DEC 3 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

57-279 O - 87 - 10

November 25, 1985

Response to Questions about the

Statement of

Dr. Keith Huston

Director-at-Large

North Central Regional Association of State Agricultural Experiment Station Directors

Before the

Committee on Science and Technology

U. S. House of Representatives

October 3, 1985

1. Acting on the priorities developed in agricultural research, how do you handle the phasing out of research activities which no longer have any priority attached to them?

In phasing out activities, one rarely finds activities of no priority. Rather the choice is among activities of greater or lesser and often shifting priority as research problems change and the resource base changes.

Research scientists, individually or in groups, are the principal resources and molders of research programs to solve problems. Scientists are specialists; they only can solve certain kinds or parts of problems. Many problems cannot be solved until teams of appropriate specialists are available. Because most research problems are solved only after years of effort, scientists must make relatively long career commitments. These factors cause research programs to be more stable than changeable. But scientists do change and so do programs.

Change occurs in a number of ways. Each scientist routinely uses flexibility within his specialty to accommodate changes in priority. In agriculture, where all research resources, including faculty time, are budgeted through a project system, those changes are readily seen when project accomplishments are reviewed annually and again at the end of the project's 3- or 5-year life. Increasingly stringent project management has become a major force in effecting incremental change.

Program redirection also can be effected easily when new faculty positions or vacancies in old positions are filled. Some Stations have added a few new positions in recent years. Most, however, have had only realignment of vacant positions. Many stations now have an unusual opportunity to effect change because faculty members added during the post World War II expansion are just now retiring. But those opportunities are not without risk. Increasingly rigid tenure standards emphasizing accomplishments of individuals rather than teams and shifts to employ more scientists qualified only as basic scientists cause change but also add inflexibility to programs.

Programs also have been changed by shifting faculty work assignments (e.g., from research to teaching or vice versa), a procedure used commonly elsewhere in the University. In agriculture, where research and teaching are budgeted separately, net gains to each function are relatively modest a determination often not makable elsewhere in the university. In recent years, considerable attention has been given to career redirection as a possible means of change.

Finally, during the 1980's, many Stations retrenched programs opportunistically when recessions forced states to cut budgets. Most stations permanently eliminated low priority projects and programs only gradually as vacant

positions permitted reconfiguration. Those retrenchments also heightened attention to long range planning.

2. Agricultural research has always had to focus some fraction on problems arising suddenly in the actual practice of agriculture, or in response to what a recent report called "nature based agricultural emergencies". How large a percentage of all agricultural research falls in this category, and what is the longer term trend in such research?

Responding to "nature based agricultural emergencies" is a normal activity in agricultural research and extension. Some emergencies require "trouble shooting" or "quick response". Many emergencies are prevented by "maintenance research".

The proportion of research devoted to "trouble shooting" is influenced by (1) the volatility of the state's agriculture and (2) the division of responsibility among research, extension and state diagnostic units and the resources available to each. Many emergencies are of recurrent types; solutions are known or at most require minor alterations through research. The large and permanent concentration of diverse research, extension, and teaching specialists on land-grant university campuses provides an important diagnostic resource that can be enlisted rapidly to safeguard the state's agriculture. Recent "trouble-shooting" research in two states required 15% and 25% of the station's resources. Cash reserves to support such large emergency research measures are difficult to maintain now in times of such tight budgets; scientists supported largely from individual grants are reluctant to respond.

Maintenance research, research to hold gains already made and to prevent emergencies, likely exceeds 50% of all agricultural research. Such research likely will increase in importance as the inherent productivity of our plants and animals moves higher and higher. For producers, when times are hard, emergencies can be the final straw, so prevention through maintenance research is important.

3. In today's environment, how successful are the several components of the agricultural research system in attracting each year a number of the younger researchers into agricultural research work? In the coming decade, how do you see the prospects for recruiting good researchers into agricultural research?

Currently, there are two visible trouble spots in attracting younger researchers into agricultural research. One is in recruiting graduate students who can be both an agricultural science specialist and an agriculturist. The other is in attracting general science Ph.D.s, usually trained outside agricultural colleges, to research agriculturally important species or problems, oftentimes as faculty of agricultural science departments. The latter

will correct itself as general scientists learn more about the agricultural research system. The former, however, is more difficult.

During the last two decades, specialization in science has increased markedly; the number of farm-reared undergraduates has declined. Agricultural researchers now are more stratified with respect to their knowledge of and interest in agriculture. Science specialists who are also agricultural generalists are essential components of the land-grant and experiment station system because they effectively develop readily useful new technology. They, thus, attract support not only for their work but also for that of their more restrictively specialized colleagues.

Unless special inducements are available to undergraduates, graduates and research faculty, the problem will persist. Unlike general and medical sciences, agricultural sciences do not generate pools of post-doctorate researchers from which research faculty can be recruited. Thus, the problems must be approached very early in the career of a prospective research scientist. The problem is exacerbated by the need for careful targeting and scaling of inducements. The number of scientists in some agricultural science specialties is very small and in others, very large. Shortages may be short- or long-lived.

Support for training agricultural scientists is an important by-product of agricultural research programs. The experiment stations are the principal source of resources for graduate education (3/4 of the graduate assistantships and most of the support resources). Shortages of trainees in some specialties indicate that research programs alone cannot be counted on to produce their own replacement scientists automatically.

4. If you were faced with a doubling of the funds available to the USDA of funds for research, how would you divide these new resources among formula funding, block grants, and individual project grants?

Doubling USDA funds in agricultural research would be a welcome and important gain to all states. Choices among funding mechanisms likely would differ among states because institutional needs vary. Doubling USDA funds in states which receive only a modest fraction of their resources from USDA would not have the same institutional impact that it would in states that derive a larger fraction of their funds from USDA.

Ranges suggested in allocations are as follows: Institutional (Formula), 50-60%; Topical or Regional Special Grant (Block Grant), 10-25%; and Topical Competitive Grant (Individual Grant), 20 to 30%.

The expanded institutional base would permit special attention to urgent equipment and instrumentation needs and refurbishing of facilities, postponed

because of recent retrenchments. It also would permit expanded interdisciplinary team building so important in agricultural systems research.

The regional share of the expanded Hatch formula funds combined with a regional block grant would permit states to enlarge their interdisciplinary and interstate cooperative research. That might also contribute to the development of interstate, multistate, and regional pacts relating to cooperative specialization among states on selected research issues.

5. In other areas where science provides a strong input to technological innovation, it has often been said that the agricultural system, including the close connection between research, extension and education could serve as a model. Yet the repeated attempts, for example by the Department of Commerce 20 years ago and more recently by some of the states, to apply the agriculture model to other industries have not had much success. Have you any thoughts why that is so?

Failure of other components of science to duplicate agriculture's success may have occurred because the following conditions did not prevail:

a. One or more clientele groups must have research needs that are economically or socially important to them and which cannot be met easily or effectively elsewhere (e.g., by private consultants, contract research firms, in-house research units)

b. Those research needs must comprise a class of problems, or be subdividable into classes of problems, each class sufficiently homogeneous as to be solvable by a specialist and sufficiently large as to require major commitment of time by a specialist for 4 or 5 years.

c. The aggregate research needs must be sufficiently numerous and diverse as to require the attention of 3 or more specialists who look to the same administrative unit for major support.

d. The needs of the clientele groups must be economically or politically important enough to elicit firm and long term commitment by state government, federal government, or universities.

e. Research scientists must believe that satisfying their clientele groups is their ultimate goal. Too often, some lesser goal may take precedence, such as earning a consulting fee or satisfying only one's self that the research was capably done.

6. Is the present structure for the management of agricultural research going to remain the same 25 years from now? Or, to put it another way, if you could write a new Act to replace the Morrill, Hatch, Evans-Allen, McIntire-Stennis,

and other Acts now governing the system to take effect in year 2000, how would you structure the agricultural research system as you think about the long-range future needs and the less useful parts of the present system?

The dual state-federal agricultural research system has worked well for many decades. Federal legislation affecting agricultural research has been changed periodically over the years in response to need.

In the next 25 years, the pivotal role of the State Agricultural Experiment Stations in federal responses to regional, national, and international issues in agriculture will need legislative attention. Required specifically will be federal legislation providing (a) greater incentives to state governments to support agricultural research, and (b) greater opportunities and incentives for stations to work together and with USDA and other federal agencies on multistate, regional, and national issues.

In the next 25 years, patterns of federal resource allocation among federal intramural programs and federal-state partnership programs likely will receive much greater attention.

Complementarities of the state and federal systems are being altered. Because the SAES of almost every state have had sufficient resources to maintain comprehensive, balanced research programs, they have responded in some measure to most "local" and "state" priorities and to many "regional" and "national" priorities. Thus, the SAES filtered out many high priority needs that otherwise might have competed legitimately for attention from the USDA agencies. The SAES serve as a buffer for the USDA agencies. Similarly, but in a much smaller way, USDA agencies buffer the SAES from federal or national priorities that might have call on federal appropriations to the SAES.

Growing complexity of research problems, increasing relative costs of doing research, greater specialization of scientists, and unusual opportunities to broaden the science dimensions of existing research fields are reducing the comprehensiveness of SAES programs. They also are siphoning off resources once used to attract and train graduate students as replacement scientists. Disquietingly, the current economic crisis in agriculture has heightened the demand for research to provide greater economic efficiencies.

Two obvious responses offer little help. States long ago exploited in fullest measure the opportunities for interstate, regional, and national collaboration provided by federal funds. Federal agencies are reducing what scattered research efforts they had that contributed simultaneously to "state" and "local" needs.

What this all likely means is that new demands for research to solve crucial problems at state and local levels will emerge in the USDA and Congress.

7. As you look over the total federal program of support for scientific research, do you see any aspects of the agricultural research system, whether it is in management, project selection, planning, funding mechanisms, or the dissemination and use of research results, that could be applied to research support in other areas than USDA's research programs?

Several features of the agricultural system might be useful elsewhere: some in university-based research programs, others in federal agencies.

In university-based research programs, the following might be useful:

a) Use of the project system as an informal, internal contract between the research scientist and his institution in accounting for all his research time, salary, and other expendable resources and for his accomplishments. External grant resources would be combined with institutional research resources not now separately budgeted.

b) Greater use of institutional research support mechanisms by federal agencies rather than individual research projects. Included might be greater emphasis on such approaches as matching; interinstitutional cooperation (as with RRF); formula allocations by demographic, geographic, or economic criteria; formula allocations by research capacity (federal or non-federal, or both) These mechanisms would support the mission of the agency and provide simultaneously for a greater diversity of initiatives and approaches in research.

c) Longer project support by awarding grants for longer periods.

In federal agencies, the following might be helpful:

a) Broader and greater interactions with user groups in assessing importance and priority of research.

b) Greater reliance on external review of research accomplishments.

c) A broader perspective of the role of federal agencies in science.

d) Greater and deliberate reliance on competition among state and federal performers and managers (e.g. USDA's intramural and partnership programs).

8. In developing the long-range plan for agricultural research, did you come up with any recommendations apart from the subject matter itself, such as for example, emphases on new methods of funding, different management approaches, and so forth?

Within states, the breadth, diversity and urgency of research needed from the agricultural experiment station always are quite evident. During the last

10 years, resources have been stretched tighter and tighter in efforts to respond to needs. What seems to be emerging from the most recent long-range planning efforts of the SAES is universal recognition of the need to work and plan together more intensely to identify urgent common priorities, expand the resource base, and use current resources more effectively.

With regard to expanding the resource base, approaches center on (a) developing more effective ways of displaying the dynamics and evolution of base programs and their benefits, (b) identifying for new funding only a few, select, new research initiatives of widest national concern, (c) choosing funding mechanisms that give greater visibility to accomplishments, and (d) selecting from tangential federal research grant programs research areas that might contribute to agricultural research.

With regard to using existing resources more effectively, approaches center on (a) wider experimenting with non-traditional program management options (b) reexamining and redefining goals, philosophy, and organization of experiment stations, resident instruction colleges, and extension services, (c) seeking shorter term, more flexible methods of involving scientists outside the station in selected station activities, and (d) exploring additional ways in which state stations may work together to share resources and responsibilities.

9. In a recent study by Dr. Lipman-Blumen, it was found that agricultural research, perhaps more than other areas of government-supported research, is subject to political influences. Specifically, such things as priority setting, laboratory closings or staffing are addressed by the Committees of the Congress. Without necessarily getting into specifics, would you comment in more general, philosophical terms on the advantages and disadvantages to a research program of such close interaction with the political system?

Close interaction with the political system has been a hallmark of agricultural research in most states and in the Congress.

At the state level, in general, those experiment stations prohibited from representing agricultural research needs before the legislature receive perceptibly smaller appropriations than those that present their needs. Generally, state legislators involved in agricultural research appropriations or oversight seek to keep research programs on target, responsive, and cost effective. They expect promises to be fulfilled later by accomplishments. Most have sufficient interest to welcome both applied and basic investigations so long as they seem in balance. Most are true friends of research. Occasionally, a legislator or a governor may overstep and interject themselves in management decisions. Occasionally, powerful interest groups may cause the legislature to appropriate funds for research on topics not of great priority to station administrators. Occasionally, requests to fund certain research investigations, particularly in the social sciences or home economics, are not received with enthusiasm or are denied by the legislature. Nonetheless most

station directors prize opportunities to interact with legislators or the governor.

Members of the Congress deal with much larger, more complex, often intractable issues than state legislators. They are more remote from everyday problems of their constituency. Nonetheless, they, too, are genuinely interested in agricultural research and its accomplishments. Congressional inquiry into priority setting, laboratory closings or staffing is an important element in keeping research programs geared to needs. Some members respond directly to requests from their constituents by seeking earmarked funds or tight control. Others are content to communicate with federal or state research administrators about such requests. Each member seems to have a finely tuned sense of the appropriate; even those committed to earmarking seem to confine themselves to symbolic responses.

As a matter of personal preference, I prefer legislators or members of Congress who take an active interest in research, who ask tough questions, who ask what taxpayers got for their money, and who, when convinced of the merits of research, will support it vigorously.

10. On Page 7 of your prepared testimony, you stated that new discoveries in agricultural research are adopted quickly and there is little unutilized technology in reserve. What is special about agricultural research that leads to such rapid technology transfer?

Most agricultural scientists are strongly mission-oriented; their administrators and extension colleagues are even more so. All are fascinated with attempting to fit new discoveries into current practices. They interact frequently enough with research users to know that users also have great interest and will respond rapidly. Indeed, on certain issues, users often will phone investigators to get the latest on their research.

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

FRIDAY, OCTOBER 4, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
TASK FORCE ON SCIENCE POLICY,
Washington, DC.

The task force met, pursuant to call, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. FUQUA. This is the third day of 6 days of hearings on the topic of Science in the Mission Agencies and Federal Laboratories.

Today we will be exploring the overall policies that apply to mission agencies in relationship with research performers including Federal laboratories, nonprofit institutions and industry.

And our first panel will examine these policies in relationship from the point of view of the mission agencies, including Dr. Alvin Trivelpiece, Director of Office of Energy Research from the Department of Energy; Dr. Orville G. Bentley, Assistant Secretary of Science and Education, Department of Agriculture; and Dr. Frank B. McDonald, Chief Scientist of the National Aeronautics and Space Administration.

Dr. Trivelpiece, we will begin with you and hear from you all, and when all of you have completed, we will have some questions at that time.

PANEL 1: MISSION AGENCIES AND EXTRAMURAL RESEARCH

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Dr. TRIVELPIECE. Thank you, Mr. Chairman.

This is the first time I have had the opportunity to appear before the task force, and I appreciate the opportunity.

The questions which you are raising and the material which you have sent out are very important questions, and they are relevant for the Nation to try to seek answers to them. Some of the questions are relatively easy to answer and easy to handle, and some of them involve kind of imponderable issues that involve the future course of the Nation. I would like to applaud the efforts of the task force to take on these questions, and I think you are doing a good job of it.

You certainly are well aware from my past testimony how important I believe science and technology are to the economic health and well-being of the Nation and to try to get these things supported well. DOE has played an important role in this collection of activities, and I believe will continue to play it in the future. It is a leader in energy and science and in national security.

Just a couple of brief statements. There are facilities in the Department of Energy, 57 of them, and 129,000 employees that are all GOCO Laboratory employees. The Department's budget, in terms of cash flow, is about $24 billion, and the reason that our appropriation is only $13 billion is we are in several businesses—that if we were an oil company, I think in terms of profits we would be one of the Seven Sisters. The revenue that flows through the Treasury is rather substantial, but the net to zero adds something like $12 to $13 billion to the cash flow of the Department.

The $13 billion appropriation is what I want to focus on for a moment. Of that, $10.9 billion goes to facilities, collectively—all the 57 facilities—and of that, $3.7 billion goes to the nine major multiprogram laboratories: Livermore, Los Alamos, Oak Ridge, Argonne, and so on. These laboratories then are involved in many different activities. We also are involved in supporting activities that are important to the Nation through the university channels that flow directly from the Department.

There is something like $345 million that goes to contracts at academic institutions. If you look at the amount that goes from the Department to laboratories to academic institutions, then there is another 300 some odd million that goes into that. If you then take into account the amount of funding that goes to places like Fermi Laboratory being distributed across the 100 universities or so on that it serves, you would roughly double that other sum. So, it would be somewhere in excess of $1 billion of Department funds that goes into the academic enterprise in the United States.

In the science area, of course, the Department is involved in the support of the high energy physics, nuclear physics, and many areas of biology and nuclear medicine research, as well as areas in such things as materials and chemistry and biology, quite a broad span of basic research. The Department's activities do span the complete spectrum from the very pure and esoteric pursuit of quarks in the nucleus of the atom to applied technology in the form of photocells and biomass.

Some 6,000 graduate students receive their support through this, and there are a number of other activities that involve the use of the laboratories for training of undergraduates and graduate students through the cooperative program.

I would like to call attention to just one thing that is mentioned in my prepared testimony which I assume is going to be made available for the record.

Mr. FUQUA. Yes. I failed to mention that at the beginning, but we will make all of the prepared statements in their entirety part of the record, and any summary of that would be in addition to that.

Dr. TRIVELPIECE. As a result of some encouragement from the Secretary who, I think, had been encouraged by the President to see what we could do in the way of additional things for high

school students this year, the Department had several programs, one of which was that we ask the Governors of each of the States to locate within their State the smartest student in mathmatics, physics and computer sciences. And then the Department arranged to take these 52 students, 1 also from the District of Columbia and Puerto Rico, out to Lawrence Livermore Laboratory and have them run on the Cray supercomputer there for 2 weeks and have lectures by leading scientists in the various areas.

I had the good fortune to go out and meet many of these youngsters who are in high school. It is a little terrifying to have a 14-year-old explaining to you some of the esoteric aspects of pure mathmatics worrying about whether or not he has a future and job security if he pursued this particular line of research. I tried to assure him he was probably eminently employable. The only problem, I think, is we have had to change all the passwords we gave them for their summer participationist activity.

The Department likes to believe that what it does, it tries to do with some degree of pursuit of excellence, and one of the statistics that we like to quote is that there are some 41 Nobel laureates of the United States who have been involved with the Department in doing their research, many of whom are still involved with them.

There are many things that your questions raise. Today, I will be happy to answer questions after my colleagues here on the panel have had their opportunity to testify.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Trivelpiece follows:]

Statement of Alvin W. Trivelpiece

Director

Office of Energy Research

Department of Energy

before the

Science Policy Task Force

of the

House Science and Technology Committee

October 4, 1985

Mr. Chairman and Members of the Task Force on Science Policy:

I am pleased to appear before you today to discuss the Department of Energy's (DOE's) policies that apply to basic and applied research and, in particular, the Department's relationships with the Federal laboratories, universities, and industrial organizations that carry out that research.

Let me begin by saying that the Department has broad mission goals that are highly science and technology intensive. DOE mission areas, very broadly stated, are energy, defense, and science. In its role of supporting research and development, the Department aims to advance the frontiers of basic scientific and technical knowledge and to support the development of new and alternative energy resources through scientific and technical research for further development and utilization by the private sector. While the missions of the Department are now clear and relatively stable, the interrelationships of the institutions that fund and carry out research in support of them, are continually evolving and changing. The dynamic nature of the research and the institutions that perform it is the one constant in our relationships with the three major R&D performing sectors--private industry, the Federal laboratories, and colleges and universities.

In considering the interrelationships among DOE and its research performers, which I will discuss in more detail in the following pages, it is important to take note of the importance of the research itself. Over the years, the technology and knowledge generated in DOE's mission areas have become a major part of the U.S. technology base and have been reapplied by industry for use in many commercial processes and products. Nuclear power, nuclear medicine, radiation processing, ion implantation, materials advances, fluidized bed coal

combustion, and supercomputers are but a few of the extensive applications of technology and knowledge that have occurred as a result of R&D sponsored by the Department.

These very real applications should not obscure the fact that basic research is long-term in nature and often contributes no immediate, measurable benefit. However, these research results add incrementally to our knowledge base. For example, bone marrow transplantation work undertaken very early in what is now DOE's Biological and Environmental Research program ultimately provided the essential underpinnings for the current state-of-the-art in organ transplant work. The result of research in any of the basic science areas may be a product, an answer to a specific question, or simply a reduction in uncertainty. The results of our scientific research, taken as a whole, comprise nothing less than an investment in our national security, economic strength, and national well-being.

Each research performer--the laboratories, universities, and private industry--have important and distinct responsibilities in assisting us to maintain a strong scientific and technological base in all energy areas. The principal criterion used by the Department in selecting the appropriate performer to carry out research is scientific and technical excellence regardless of the location and type of performer. The competitive process provides us with the assurance that the best research will be supported.

BACKGROUND

The evolution in the relationships with our research performers began in the 1940's when the Manhattan Project was expanded into the Atomic Energy Commission. In those early days, the majority of the Commission-sponsored research was done by a complex of national laboratories through a unique contractual partnership with universities and industry. Several of the Government-owned, contractor-operated laboratories were multidisciplinary in nature because of the need for expertise in virtually all of the sciences as they related not only to the Manhattan Project but to the later inclusion of nuclear power research as a laboratory mission. The multidisciplinary nature of the laboratories' missions expanded even more with the establishment of the Energy Research and Development Administration. Today, the DOE laboratory complex comprises the largest group of Government-owned, contractor-operated facilities in the U.S. and, indeed, in the world. In addition to their multidisciplinary capabilities, all of the multiprogram laboratories have extensive research facilities and the ability to assemble project or program teams on a rapid-turnaround basis. Taken together, the expertise, equipment, facilities, and capabilities at the national laboratories represent a true national research and development resource.

These national laboratories do not exist in isolation. They have a long history of relationships with the university and industry communities through a variety of mechanisms. Some laboratories have particularly close relationships with universities because their operating contractor is a university or a university consortium. In almost all laboratories, large numbers of university faculty and students (sometimes up to 20% of the full-

time equivalent staff) work for extended periods. It is the policy of the Department to make its laboratories and facilities available to qualified scientists who can make the best use of these capabilities. This includes major DOE facilities with associated equipment and instruments, which are officially designated as either national research facilities (e.g., Stanford Linear Accelerator Center and the Fermi National Accelerator Laboratory) or user facilities at one of the major multiprogram laboratories. The interaction of laboratory and university staffs at these facilities brings together some of the best scientific minds in the Country in an effort that not only produces good science but helps to train students who will carry their new knowledge and experience into future careers in both the Government and the private sector.

Within this general policy guidance, there is continued emphasis on university involvement, both from a research and from a training perspective. As noted, university researchers are essential participants in all DOE-sponsored R&D. In FY 1985 alone, direct funding for universities totalled approximately $345 million. In part, these funds supported some 3000 to 3500 graduate students working on university projects as well as an additional 2000 to 3000 graduate students supported indirectly through the laboratories. We estimate that an additional $300-350 million was provided in FY 1985 in indirect support through the laboratories for university related research. This includes the use of laboratory research facilities and instrumentation by faculty and students and summer research participation of university scientists at the laboratories. Several of our laboratories have particularly close ties with nearby universities. For example, Oak Ridge National Laboratory and the University of Tennessee have collaborated on the development of a joint Distinguished Scientist Program. Similar cooperative efforts are in place

between the University of New Mexico and our Sandia and Los Alamos Laboratories and between the Pacific Northwest Laboratory and regional universities and colleges.

Laboratory relationships with industry also have been significant. The history of the development of the nuclear power industry is but one example of the fruits of such relationships. Currently, relationships generally take the form of subcontracting with industry for technical and engineering analyses and component and hardware development, and participation by industrial scientists on DOE laboratory advisory and peer review groups. Industry personnel are increasingly working side by side with laboratory staff on problems of mutual interest and utilizing DOE user research facilities. Two facilities funded by ~~the Department~~'s Office of Energy Research are among those offering ever-increasing access to industrial researchers. They are the Combustion Research Facility at Sandia-Livermore where the focus is on laser diagnostics of combustion systems and the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory. The NSLS is a valuable research tool serving the physics, materials, chemical, and biological research communities. The NSLS operates 24 hours a day, seven days a week and attracts both industrial and university researchers.

Industrial users have spent in excess of $7 million dollars at NSLS to build special beam lines for special research purposes. IBM, for example, has built a special beam line to conduct research on x-ray lithography, a process of great potential for the production of computer chips a fraction of their current size. Furthermore, these industry-funded beam lines are made available for a portion of the time to the general research community.

CURRENT AND FUTURE DIRECTIONS

Policy regarding the use of the major research performers--Federal laboratories, universities, and industry--has resulted over the years in a balanced approach aimed at using the best performer for a given task. Administration policy calls for increased reliance on the private sector for technological advancements of interest to the marketplace but recognizes an appropriate Federal role in long-term research in the national interest beyond what can be expected from the private sector. The Department's policy regarding support for basic and applied research is to maintain core research programs in the laboratories, particularly in situations where capital-intensive equipment is required, long-term research is entailed, or where research aimed at developing new energy technologies involves large uncertainties or important energy-related environmental factors.

DOE policy also continues to stress the importance of university research to the development of new and innovative scientific and technical concepts and to the preparation and training of students. Our commitment to training students for future careers in science and engineering also extends to the precollege level. We have sponsored a series of summer research and training institutes at the laboratories for high school science students. The most unique effort was our recent High School Supercomputing Honors Institute held this past August at Livermore and involving 52 high school students representing each state, Puerto Rico and the District of Columbia. We will be building on these

efforts in the next year as we strongly believe that the scientists and research facilities at our laboratories can play important roles in the national effort to strengthen the science and mathematics programs in our secondary schools.

Both the universities and the laboratories are key links in the transfer of technology into the private sector. This transfer of knowledge and, ultimately, technology into use in the private sector where it can contribute to the Nation's economic health and well-being and national security is our overriding goal. The DOE R&D Laboratory Technology Transfer Program, managed by the Office of Energy Research, was implemented in response to the Stevenson-Wydler Technology Innovation Act. The purpose of the technology transfer program is to facilitate improved use by State and local governments and the private sector of federally funded technology developments to strengthen the U.S. industrial base and competitive position in the international marketplace. The key to the transfer of technology is person-to-person interactions between our laboratory researchers and industry counterparts. As noted earlier in my testimony, we are providing increasing opportunities for industry involvement at the laboratories and have encouraged the laboratories to identify appropriate laboratory technology and inform interested firms. One recent effort in this regard was the initiation of our Laboratory Industry Technology Exchange Program. Through this program, industrial scientists are spending up to a year in a visiting research appointment at a DOE laboratory working on research of mutual interest to both the laboratory and the scientist's company. In FY 1985 12 appointments were made at 7 laboratories. The appointments are jointly funded by the laboratory and the industrial company.

In summary, DOE policy and practices are aimed at improving the laboratory management process and the accessibility of the laboratories to university and industry researchers. Specifically, the Department has established:

--an institutional planning process that will provide a continuing opportunity to reexamine laboratory missions;

--an annual laboratory appraisal process which will contribute to optimum research and management performance;

--an improved technology transfer program;

--a central Headquarters council to address broad R&D policy issues in a timely manner; and

--a new patent and work for others policy that provides the laboratories more opportunities to increase interactions with the private sector.

In addition, the Department is committed to:

--involving university scientists, as appropriate, in all energy research and development programs;

--recognizing the educational benefits of DOE-sponsored research by encouraging and providing support for student participation in research;

--encouraging interaction and collaboration in energy research among university, industrial and national laboratory groups;

--expanding opportunities for university faculty and students to utilize the special and unique facilities and equipment at the DOE laboratories; and

--streamlining pre- and post-award grants procedures to aid in decreasing the administrative burden on DOE research grant recipients and the Federal Government. (Also, we will be looking closely at the recommendations in this area from the National Academy of Sciences Government/University/Industry Roundtable.)

I believe that it is clear from the policies and trends that I have summarized that the Department fully recognizes the immense value to the Nation of the R&D programs it supports and the importance of the R&D performers who carry them out. Perhaps equally as important, we recognize the need to be responsive to changing circumstances, needs, and opportunities both from an international and a domestic perspective. In this effort, we will continue to use the advice of our research performers, our technical and policy advisory groups, and the Congress. In this context, we look forward to the results of the work being done by your Science Policy Task Force.

Mr. Chairman, that concludes my prepared statement. I have touched broadly on a few of the many important issues related to science policy and will be happy to respond to your questions in more detail.

Mr. FUQUA. Thank you very much, Dr. Trivelpiece.
Dr. Bentley.
[A biographical sketch of Dr. Bentley follows:]

DR. ORVILLE G. BENTLEY

Orville G. Bentley serves as the Nation's first Assistant Secretary for Science and Education. He was sworn in October 19, 1982, by Secretary of Agriculture John R. Block.

The South Dakota native is responsible for directing evaluating the U.S. Department of Agriculture's role in the food and agricultural sciences. Under Dr. Bentley's leadership, the mandated Joint Council on Food and Agricultural Sciences has made great strides in targeting and promoting future efforts in research in the sciences that affect the food and fiber industries. The published reports produced by various satellite committees of the Joint Council have had great impact on the agriculturally-oriented science and education communities, the agricultural industry, and other government agencies concerned with food, nutrition, chemicals, and the environment.

In response to planning activities led by Dr. Bentley, a new $20 million Biotechnology Competitive Grants Research initiative was established. Major program redirections were started by the Agricultural Research Service, Extension Service, and the National Agricultural Library. Dr. Bentley currently serves on many committees and boards, among which are the Government-University-Industry Roundtable, the Cabinet Council's Subcommittee on Biotechnology, and the Interagency Committee on Human Nutrition Research.

Dr. Bentley earned his B.S. degree from South Dakota State College in 1942, majoring in agriculture and chemistry. After serving four years in the United States Air Force, where he rose to the rank of Major, he received M.S. and Ph.D. degrees from the University of Wisconsin in 1947 and 1950, respectively. In recent years he has received Honorary Doctor of Science Degrees from both these universities, and Distinguished Service Awards from the Alumni Associations at South Dakota State University and the University of Illinois Urbana-Champaign.

STATEMENT OF DR. ORVILLE G. BENTLEY, ASSISTANT SECRETARY, SCIENCE AND EDUCATION, U.S. DEPARTMENT OF AGRICULTURE, WASHINGTON, DC

Dr. BENTLEY. Thank you.

Mr. Chairman, I am pleased today to have an opportunity to appear before the panel, and I, too, want to express appreciation for the efforts of the committee in the work you are doing on behalf of science and technology. And, of course, I need not say to you who have been involved with it the importance of this to the future of our country.

The Department of Agriculture is really facing a number of questions, and American agriculture is facing a number of questions.

But at the same time we are going through a period of great change, and during that time we think there are great opportunities for adjustment and change that will be taking place in the Nation's food and fiber system, primarily, in that science and technology will have an important role in this question.

A better perspective—it is appropriate to note that we are faced with a number of paradoxes. One is that some people feel that the success of agricultural science and research is contributing to the agricultural problems, and it is true that farmers and ranchers have used technology and resources to increase the yields of crops and livestock, but it is also appropriate to recall that just a few short years ago the major question before many people was: "Will there be enough food in the world?" And yet today we talk about commodity stockpiles and production that is exceeding market

demand, and there is a great deal of concern about production cutbacks.

But there have been—we also must remember there have been—a series of major changes taking place in production agriculture, and we must not overlook the fact that production agriculture is important because we are thinking in terms of food and fiber needs of this country and for the world markets, and therefore, we have to continue to give a great deal of emphasis to this area.

We also are concerned, or must note, that there is a change in the basic justification for research that is most appropriate for the times. In other words, if we are talking about a more market-driven agriculture, we have to think in terms of productivity and utilize every opportunity that is available to us to reduce costs, to enhance the quality of the products that are produced, and thereby make it possible for farmers and ranchers to produce effectively and profitably in today's market situation and probably the way it is in the future.

It is also important to remember that, when we think in terms of longer term goals and objectives, that farmers have immediate needs, and one can refer to the old statement that says—that goes about like this—that a farmer talking about long-term needs with a researcher. The farmer reminds the researcher that: "Bugs are eating my crop right now, and I need action, and I need attention to problems immediately."

So, this is the general framework in which we are working, and we are thinking about the future of American agriculture and industry, and I want now to refer to some comments related to science and technology as a part of your oversight hearings.

The agricultural science policies are all too frequently based upon reactive strategies, maintaining of our ability to divert from a charted course or undertake special mission needs that are brought about through immediate problems. To meet the challenges which face agriculture, the public system has worked together in the long-term development process as a basis of resource allocation. We do have a course of action charted. We do have priorities.

You have asked in your questions who sets the priorities and what criteria are used. There are two distinct levels of research programs that USDA, the in-house or Intermural Research Program which is conducted through the Agriculture Research Service, and the Cooperative Research Program which is coordinated by the Cooperative State Research Service. The CSR's program operates primarily through the 1862 and the 1890 land-grant institutions, and that includes Tuskegee University as well. These State universities, with priorities in the final analysis, determine the level of allocations and programs. However, there is a joint effort in the priority-setting process.

As an example of this dialogue, the needs assessment was conducted by the Joint Council on Food and Agriculture Sciences. I have submitted a copy of the report to the committee. I will just merely hold this one up to call attention to it.

The Joint Council is the organization which coordinates research activities in food and agriculture sciences. The National Agriculture Research Committee, the National Extention Committee and the National Higher Education Committee, as well as the USDA

agencies, such as Forest Service and Economic Research Service, contribute to the priority-setting process. The recommendations of the Joint Council are then forwarded to the Secretary of Agriculture. They are also made available to the heads of the non-Federal partners in the Agriculture Research System.

Again, I have provided the members of the task force with a copy of the current report of the Joint Council which details the fiscal year 1987 priorities for research, extension, and higher education, and I will call attention to this report as well.

As Assistant Secretary, I have accepted these reports and have directed the agencies under my jurisdiction to utilize them in setting individual agency priorities. These are: one, increased agricultural profitability through management; improve water quality and management; expand biotechnology efforts on plants, animals, and microbes; develop necessary scientific and professional human capital; and five, to improve human nutrition and understanding of diet, health relationships.

These—behind each of these reports are detailed statements concerning them, but I will not mention those in our conversations this morning.

Within our agencies and in the Competitive Grants Program of the USDA, this list of priorities is given serious consideration as we determine project funding and based upon specific recommendations from peer reviewers.

We have a number of advisory boards in each of these areas. The largest independent advisory board is the Users Advisory Board, which differs from the Joint Council in that it is composed of users of the agricultural sciences. These two organizations have joint meetings and do coordinate many of their activities. The individual advisory boards do have their respective priorities, and I make a concerted effort to consider their recommendations in individual areas.

The USDA fully recognizes the responsibilities to other Federal agencies, and I believe Dr. Kinney, yesterday in his remarks, made reference to these relationships as they affect his particular Agency, the Agriculture Research Service.

I want to take a moment to discuss the role of the Office of Science and Technical Policy and the Federal Coordinating Council on Science, Engineering and Technology [FCCSET].

Dr. Keyworth and his staff at OSTP have been highly supportive through policy guidelines for Federal science and education programs as they relate to agriculture.

Also, within the Federal Government, I confer with the administrators of FDA on matters relating to nutrition and biotechnology, and it also calls for frequent contacts with the EPA on agricultural chemical issues and the Department of Health and Human Services on nutrition research priorities.

Those of us in the Federal sector do try to attempt to coordinate our activities, and we look to OSTP to assist us in that particular effort. One of the questions sent to me by the committee had to do with crash programs and their impact on research. In agriculture, we do use crash projects, so to speak. Within the past year we have had to react to outbreaks of citrus canker in Florida, to withdrawal of ethylene dibromide as a fumigant, to an outbreak of avian flu in

poultry and the misuse of the chemical aldicarb which resulted in serious economic harm to the Nation's watermelon producers. Such problems do drain resources, but both the Office of Management and Budget (OMB) and the Congress have been responsible in providing funds when we need to deal with crash program requirements.

You have raised a question about relating to the role of the Department of Defense in basic research and the optimum balance between civilian and military research. In the interest of time, let me just summarize by saying we do have some cooperative relationships, and I have detailed those in my testimony, but at the current moment there is approximately $900,000 worth of research that is carried out under a memorandum of agreement. A copy of a statement relative to these programs has been provided to the committee, and I will hold it up to identify it for this purpose. The kinds of research covered have to do with nutrition, disease and insect control, wood preservation, protective systems for military subsistence in fabrics and food stuff fumigants. These, again, have been referred to in the memorandum.

With regard to our relationships with extramural research performers at USDA, the primary responsibility for such relationships is delegated to the Cooperative State Research Service and the administrator of that agency, Dr. Pat Jordan has provided you with detailed information concerning these activities.

It is appropriate to note here from the time of Abraham Lincoln this Nation has recognized the talents and the abilities of our colleges and universities, and today, with the advent of biotechnology, we are experiencing a reaffirmation in the increased intensity in this particular area.

Turning now to biotechnology, the USDA initiative in the last year in the Competitive Grants Program was aimed at exploiting the scientific opportunities for agriculture at all eligible institutions and laboratories that have the capacity to perform research on agriculturally related problems. This competitive program which was supported by the Office of Science and Technology Policy has generated a great deal of interest throughout the country. In recent months we have proposed revisions, for example, of the Research Facilities Acts which will allow institutions—land grant and non-land grant universities—to compete for funds on a matching basis for the acquisition of new facilities and equipment, and this is aimed at strengthening the capacity of our country to meet these new opportunities and challenges.

Our cooperative relationship with the private sector is also receiving a great deal of attention. Dr. Kinney has described ARS's Technology Transfer Program, and I have briefly cited just a couple of examples of such cooperative effort. Last March, ARS executed an agreement with GENEX to participate in the development of a vaccine for coccidiosis, a poultry disease. ARS is presently proposing to solicit at this time on a private basis, funds to develop a similar vaccine for trichinosis in swine.

Mr. Chairman, there is one area of great challenge to the agriculture research system. It is in the area of our relationship with the private sector. Historically, the private sector has been reluctant to exchange basic research information about the Government

simply because the Government could not guarantee that the product development, as a result of such research, would not be in, quote, the public domain.

Conditions are changing. Today, we can issue exclusive licenses to private sector companies to develop and market products which have been invented by Government scientists.

There are several pieces of legislation proposed which would allow Government laboratories to enter into private partnerships with private sector firms and institutions. We would welcome expansion of this opportunity, as we believe such relationships would be mutually beneficial. In this regard, we are working with Dr. Bruce Merrifield, the Assistant Secretary of Commerce for Productivity, Technc logy and Innovation.

As to the relationshp of the USDA to science and engineering infrastructure, you pose a number of important and relevent questions.

You have asked about the availability of qualified scientific and technical personnel to meet present and projected needs. It is certainly no secret that the number of post-doctoral students in agriculture has been declining. To change that trend, we have sponsored a Pre-Doctoral Grant Program aimed at attracting outstanding science-oriented students to pursue advanced degrees in food and agricultural sciences. This is a modest program and one which may have to be accelerated unless the present trend is reversed. There is growing competition for agricultural scientists. In the USDA, we have a number of incentive programs for our scientists: Bonus payments for outstanding work and modest payment for product patents. We have established a special employment catagory to employ a limited number of scientists on a short-term basis at the post-doctorate level. We will have to become even more innovative in the future if we are to remain competitive for personnel.

I would be remiss if I did not mention the important role which is being played by our historically black institutions in training future scientists. The 1890 institutions, Tuskegee University and the University of the District of Columbia, are all partners in the Federal system, and we have earmarked funds for Student Development Programs at these institutions.

A large network of research institutions in the public sector became necessary several years ago to develop and refine the capability of providing an inventory of products and research planning. The Current Research Information System, commonly referred to as CRIS, provides the on-line capability. This system allows specific searches by title, project, subject, and geographic area. I have here—I have a sample copy of the CRIS research reports. This happens to be a listing of all remote sensing projects, and I will give you an idea of the system and its capabilities, and here again is an example of the printout in this particular area.

The decisions of regulatory agencies impact farmers and ranchers. Decisions by the EPA and the protection of EPA often require technical responses from USDA. An example—as an example—USDA performs benefit analysis on those agricultural chemicals which are under special review status by EPA. These reviews are designed to provide information to EPA which it can use in making a final determination as to the fate of a special chemical. If, for in-

stance, a chemical is known to have adverse impacts on the environment, is there a suitable alternative? Will the withdrawal of the chemical cause undue economic hardship on the agricultural community? Are there alternatives to outright withdrawal, such as the Pesticide Applicator Program, specific use allowance and such?

Such studies are best done by USDA because we have the information network needed to obtain such data. In all instances where the USDA research is produced for regulatory agencies, we do attempt to issue results in a form that can be readily translated by the regulators. Research science often interacts directly with representatives from the regulatory agencies.

The final subject I was asked to comment on briefly involved Federal laboratories. Dr. Kinney, in his presentation on ARS yesterday, gave you an overall view as to the organization and the assignment of work in ARS laboratories. We are well pleased with the relationship which ARS has had in working with universities, including the sharing of laboratory facilities and personnel. The same general comments can be made for the laboratories administered by the Forest Service. One of the objectives I have, is to see an expansion and continuation and strengthening of these relationships over the years ahead.

The last question which you posed, deals with the policy towards establishment of new Federal laboratories and the reorientation of existing facilities. We must maintain our position as a world leader in scientific research, and this means we must devote our attention to program improvements rather than construction projects at this time.

To repeat, we are in an era of dynamic development in the agricultural sciences. There is a sense of excitement and high expectation in the research community that is shared by the leadership in the USDA. I am fully confident that the joint Federal-State system is up to the challenge if we can support them adequately in the years ahead.

I appreciate the opportunity to meet with you and make this presentation.

[The prepared statement of Dr. Bentley follows:]

STATEMENT OF

DR. ORVILLE G. BENTLEY

ASSISTANT SECRETARY

SCIENCE AND EDUCATION

U.S. DEPARTMENT OF AGRICULTURE

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

OCTOBER 4, 1985

MR. CHAIRMAN AND MEMBERS OF THE TASK FORCE ON SCIENCE POLICY, I WELCOME THIS OPPORTUNITY TO APPEAR BEFORE YOU TODAY TO DISCUSS THE U.S. DEPARTMENT OF AGRICULTURE'S RESEARCH PROGRAMS. THIS IS A MOST CRITICAL TIME FOR AMERICAN AGRICULTURE. THERE ARE OPPORTUNITIES FOR CHANGE AND ADJUSTMENTS. WE MUST PURSUE THESE OPPORTUNITIES IN SEARCH OF CONSTRUCTIVE CHANGES FOR THE NATION'S FOOD AND FIBER PRODUCERS AND THE ALLIED INFRASTRUCTURE THAT FORMS THE SYSTEM.

THERE ARE THOSE WHO MIGHT SUGGEST THAT TODAY'S PROBLEMS IN AGRICULTURE COULD BE BLAMED IN PART ON THE SUCCESSES OF AGRICULTURAL RESEARCH. FARMERS AND RANCHERS HAVE USED TECHNOLOGY AND RESOURCE MANAGEMENT SKILLS TO INCREASE YIELDS IN CROPS AND LIVESTOCK PRODUCTION. JUST A FEW SHORT YEARS AGO, THE QUESTION WAS "WILL THERE BE ENOUGH FOOD?" BUT TODAY, COMMODITY STOCKPILES ARE OVERFLOWING AND THERE ARE PROGRAMS TO ENCOURAGE PRODUCTION CUTBACKS.

IN JUST A FEW SHORT DECADES REMARKABLE AND FUNDAMENTAL CHANGES HAVE OCCURRED IN AGRICULTURE, AND THAT INCLUDES AGRICULTURAL SCIENCE. PRODUCTION AGRICULTURE IS IMPORTANT. WE MUST ALWAYS MAINTAIN THE ABILITY TO MEET MARKET DEMANDS -- BUT EQUALLY IMPORTANT ARE PRODUCTION EFFICIENCY, MARKETING, AND UTILIZATION. WE ARE PRODUCING FAR MORE FOOD AND FIBER THAN CAN BE UTILIZED IN TODAY'S MARKETPLACE. AND, INCREASED COMPETITION IN WORLD MARKETS, COUPLED WITH OTHER ECONOMIC FACTORS, HAS BROUGHT ABOUT A DECREASE IN EXPORT SALES OF AGRICULTURAL PRODUCTS.

WE HEAR THE EXPRESSION "MARKET DRIVEN AGRICULTURE" FREQUENTLY. LIKEWISE, AGRICULTURAL SCIENCE IS BECOMING MORE MARKET DRIVEN. PROFITABILITY IS BEGINNING TO PARALLEL PRODUCTIVITY AS A PRIORITY, THEREFORE IT IS NECESSARY TO IDENTIFY TECHNOLOGIES THAT IMPROVE PRODUCTIVITY THROUGH COST REDUCTIONS, ENHANCE PRODUCE QUALITY, AND LESSEN THE ADVERSE EFFECTS OF PESTS AND HARSH ENVIRONMENTS.

AND, THE NEW TECHNOLOGIES ARE COMING ON LINE AT A MOST OPPORTUNE TIME. I WILL TALK WITH YOU IN A FEW MINUTES ABOUT OUR NEW THRUSTS IN BIOTECHNOLOGY AND GENETIC ENGINEERING. BUT, BEFORE I GET TO THAT, I AM REMINDED OF THE OLD STORY ABOUT THE RESEARCHER WHO WAS TELLING THE FARMER ABOUT THE WONDERFUL THINGS SCIENCE WAS GOING TO DO FOR AGRICULTURE IN THE FUTURE. THE FARMER INTERRUPTED HIM AND SAID, "THAT'S GOOD, BUT THE BUGS ARE EATING MY CROP RIGHT NOW."

MR. CHAIRMAN, WE DO HAVE IMMEDIATE PROBLEMS EATING AT THE VERY HEART OF AMERICAN AGRICULTURE. IT IS A PROBLEM WHICH MUST HAVE OUR IMMEDIATE ATTENTION. NOT ONLY ARE OUR FARMERS AND RANCHERS CONFRONTED WITH ECONOMIC PROBLEMS, BUT THEY ARE BESET WITH WHAT MIGHT BEST BE DESCRIBED AS AGRICULTURAL ENVIRONMENTAL POLICY PROBLEMS - PARTICULARLY IN THE AREA OF AGRICULTURAL CHEMICALS AND LAND USE.

IT IS IMPORTANT FOR THIS TASK FORCE TO UNDERSTAND THAT THE MAIN THRUST OF OUR ACTIVITIES IS DIRECTED SQUARELY AT ADDRESSING THOSE ISSUES WHICH ARE IMPERILING NOT ONLY TODAY'S AGRICULTURE -- BUT THE FUTURE OF THE AMERICAN AGRICULTURAL INDUSTRY.

AGRICULTURAL SCIENCE POLICIES ARE FREQUENTLY BASED UPON REACTIVE STRATEGIES -- MAINTAINING THE ABILITY TO DIVERT FROM A CHARTED COURSE TO UNDERTAKE THOSE SPECIAL MISSIONS NECESSARY TO RESOLVE IMMEDIATE PROBLEMS. TO MEET THE CHALLENGES WHICH FACE AGRICULTURE, THE PUBLIC SYSTEM HAS WORKED TOGETHER IN PROGRAM DEVELOPMENT AND RESOURCE ALLOCATION. WE DO HAVE A COURSE OF ACTION CHARTED. WE DO HAVE PRIORITIES.

YOU ASKED "WHO SETS THE PRIORITIES AND WHAT CRITERIA ARE USED?" THERE ARE TWO DISTINCT LEVELS OF RESEARCH PROGRAMS AT USDA -- THE IN-HOUSE RESEARCH WHICH IS CONDUCTED BY THE AGRICULTURAL RESEARCH SERVICE -- AND THE COOPERATIVE RESEARCH PROGRAM WHICH IS COORDINATED BY THE COOPERATIVE STATE RESEARCH SERVICE. THE CSRS PROGRAM OPERATES PRIMARILY THROUGH THE 1862 AND 1890 LAND GRANT INSTITUTIONS -- AS WELL AS AT TUSKEGEE UNIVERSITY. THESE ARE STATE INSTITUTIONS -- WITH PRIORITIES IN THE FINAL ANALYSIS BEING DETERMINED AT THAT LEVEL.

HOWEVER, THERE IS A JOINT EFFORT IN THE PRIORITY-SETTING PROCESS. THE JOINT COUNCIL ON FOOD AND AGRICULTURAL SCIENCES IS THE ORGANIZATION WHICH COORDINATES RESEARCH ACTIVITIES IN THE FOOD AND AGRICULTURAL SCIENCES. THE NATIONAL AGRICULTURAL RESEARCH COMMITTEE, THE NATIONAL EXTENSION COMMITTEE, AND THE NATIONAL HIGHER EDUCATION COMMITTEE, AS WELL AS USDA AGENCIES SUCH AS THE FOREST SERVICE AND ECONOMIC RESEARCH SERVICE, CONTRIBUTE TO THE PRIORITY- SETTING PROCESS. THE RECOMMENDATIONS OF THE JOINT COUNCIL ARE THEN FORWARDED TO THE SECRETARY OF AGRICULTURE. THEY ARE ALSO MADE AVAILABLE TO THE HEADS OF THE NON-FEDERAL PARTNERS IN THE AGRICULTURAL RESEARCH SYSTEM. I HAVE PROVIDED EACH MEMBER OF THIS TASK FORCE WITH A COPY OF THE CURRENT REPORT OF THE JOINT COUNCIL WHICH DETAILS FY 1987 PRIORITIES FOR RESEARCH, EXTENSION, AND HIGHER EDUCATION.

57-279 O - 87 - 11

AS THE ASSISTANT SECRETARY FOR SCIENCE AND EDUCATION, I HAVE ACCEPTED THIS REPORT AND HAVE DIRECTED THE AGENCIES UNDER MY JURISDICTION TO UTILIZE THIS REPORT IN SETTING INDIVIDUAL AGENCY PRIORITIES. THOSE PRIORITIES ARE:

1. INCREASE AGRICULTURAL PROFITABILITY THROUGH MANAGEMENT.
2. IMPROVE WATER QUALITY AND MANAGEMENT.
3. EXPAND BIOTECHNOLOGY EFFORTS ON PLANTS, ANIMALS, AND MICROBES.
4. DEVELOP NECESSARY SCIENTIFIC AND PROFESSIONAL HUMAN CAPITAL.
5. IMPROVE HUMAN NUTRITION AND UNDERSTANDING OF DIET/HEALTH RELATIONSHIPS.

IN THE REPORT, YOU WILL FIND THE DETAILED DESCRIPTIONS OF EACH OF THESE FIVE PRIORITIES.

WITHIN OUR OWN AGENCIES, AND IN THE COMPETITIVE GRANTS PROGRAMS OF USDA, THIS LIST OF PRIORITIES IS GIVEN SERIOUS CONSIDERATION AS WE DETERMINE PROJECT FUNDING -- BASED UPON SPECIFIC RECOMMENDATIONS OF PEER REVIEWERS.

WE HAVE A NUMBER OF ADVISORY BOARDS, EACH WITH A SPECIFIC MISSION. THE LARGEST INDEPENDENT ADVISORY BOARD IS THE USERS ADVISORY BOARD -- WHICH DIFFERS FROM THE JOINT COUNCIL IN THAT IT IS COMPOSED OF USERS OF THE AGRICULTURAL SCIENCES. THESE TWO ORGANIZATIONS DO HAVE JOINT MEETINGS AND DO COORDINATE MANY OF THEIR ACTIVITIES. THE INDIVIDUAL ADVISORY BOARDS DO HAVE THEIR RESPECTIVE PRIORITIES AND I MAKE A CONCERTED EFFORT TO CONSIDER THEIR RECOMMENDATIONS IN INDIVIDUAL PROGRAM AREAS.

USDA FULLY RECOGNIZES ITS RESPONSIBILITIES TO THE OTHER FEDERAL AGENCIES -- AND I BELIEVE DR. KINNEY, THE ADMINISTRATOR OF THE AGRICULTURAL RESEARCH SERVICE, HAS TOUCHED UPON THE RELATIONSHIP HIS AGENCY HAS WITH MANY OF THESE AGENCIES. I WANT TO TAKE JUST A MOMENT ABOUT THE ROLE OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP), AND THE FEDERAL COORDINATING COUNCIL ON SCIENCE, ENGINEERING, AND TECHNOLOGY (FCCSET).

DR. GEORGE KEYWORTH AND THE STAFF OF OSTP HAVE BEEN OF TREMENDOUS HELP IN PROVIDING POLICY GUIDANCE FOR FEDERAL SCIENCE AND EDUCATION PROGRAMS. THE CONGRESS AND THE AMERICAN PEOPLE BECOME CONCERNED OVER THE POSSIBILITY OF WASTEFUL DUPLICATION IN SCIENCE PROGRAMS. YET, AS I INTERACT WITH MY COUNTERPARTS AT THE DEPARTMENT OF HEALTH AND HUMAN SERVICES, THE ENVIRONMENTAL PROTECTION AGENCY, AND OTHER FEDERAL AGENCIES, I FIND LITTLE, IF ANY, OUTRIGHT DUPLICATION OF EFFORT. SINCE RESEARCH IS "PROBLEM SPECIFIC" THERE MAY BE INSTANCES WHERE TWO OR MORE AGENCIES MAY, IN FACT, BE WORKING ON A SIMILAR PROJECT. HOWEVER, BECAUSE SUCH WORK IS ALSO SITE SPECIFIC, DIFFERENT FINDINGS MAY BE OBTAINED. FOR EXAMPLE, RESEARCH INTO THE APPLICATION OF PESTICIDES ON CORN MAY BE CONDUCTED IN FLORIDA AND IN ILLINOIS. BUT BECAUSE OF THE DIFFERENT CLIMATES AND SOILS, THE PROJECTS -- ALTHOUGH IDENTICAL IN NATURE, WOULD ACTUALLY BE UNIQUE.

WITHIN THE FEDERAL GOVERNMENT, I OFTEN CONFER WITH THE ADMINISTRATOR OF THE FOOD AND DRUG ADMINISTRATION ON MATTERS RELATING TO NUTRITION AND BIOTECHNOLOGY. I FREQUENTLY INTERACT WITH THE ENVIRONMENTAL PROTECTION AGENCY ON AGRICULTURAL CHEMICAL ISSUES. THOSE OF US IN THE FEDERAL SECTOR DO COORDINATE OUR ACTIVITIES AND OSTP PLAYS A KEY ROLE IN SUCH EFFORTS.

I TURN NOW TO YOUR QUESTION RELATING TO HOW "CRASH PROGRAMS" IMPACT OUR RESEARCH ACTIVITIES. IN AGRICULTURE, WE ARE USE TO "CRASH PROJECTS." WITHIN THE PAST YEAR, WE HAVE HAD TO REACT TO AN OUTBREAK OF CITRUS CANKER IN FLORIDA, TO A WITHDRAWAL OF ETHYLENE DIBROMIDE (EDB) AS A FUMIGANT, TO AN OUTBREAK OF AVIAN FLU IN POULTRY, AND THE MISUSE OF THE CHEMICAL ALDICARB WHICH RESULTED IN SERIOUS ECONOMIC HARM TO THE NATION'S WATERMELON PRODUCERS. SUCH PROJECTS DO DRAIN RESOURCES -- BUT BOTH THE OFFICE OF MANAGEMENT AND BUDGET, AND THE CONGRESS HAVE BEEN RESPONSIVE IN PROVIDING FUNDING NEEDED TO PAY FOR SUCH "CRASH PROGRAMS."

YOU HAVE RAISED A QUESTION REGARDING THE ROLE OF THE DEPARTMENT OF DEFENSE IN BASIC RESEARCH AND THE "OPTIMUM BALANCE" BETWEEN CIVILIAN AND MILITARY RESEARCH. MR. CHAIRMAN, IN 1982 A FORMAL MEMORANDUM OF UNDERSTANDING WAS EXECUTED BETWEEN USDA AND DOD. AS A RESULT OF THAT DOCUMENT, WE HAVE AN COOPERATIVE RELATIONSHIP WITH DEFENSE. DOD IS PRESENTLY FUNDING IN EXCESS OF $900,000 IN AGRICULTURAL RESEARCH THROUGH THE AGRICULTURAL RESEARCH SERVICE. ARS ALSO EXPENDS ADDITIONAL FUNDS IN SUPPORT OF DOD RESEARCH PROJECTS. THE MAIN AREAS OF MUTUAL INTEREST, AS DEFINED THROUGH THE MEMORANDUM, ARE NUTRITION RESEARCH, DISEASE AND INSECT CONTROL, WOOD PRESERVATION, PROTECTIVE SYSTEMS FOR MILITARY SUBSISTENCE AND FABRICS, AND FOODSTUFF FUMIGANTS. I HAVE SUBMITTED FOR YOUR INFORMATION AND REVIEW TWO DOCUMENTS RELATING TO THIS SUBJECT, THE FIRST IS A LETTER OF MAY 21, 1984 FROM DOD TO USDA WHICH CONTAINS DOD'S RECOMMENDATIONS FOR USDA PEST MANAGEMENT RESEARCH. THE SECOND DOCUMENT IS A COPY OF THE DOD FOOD AND NUTRITION RESEARCH AND ENGINEERING PROGRAM FOR FISCAL YEARS 1986, 87, AND 88 WHICH HAS BEEN TRANSMITTED TO USDA IN ORDER TO KEEP US FULLY ABREAST OF THEIR RESEARCH ACTIVITIES IN THESE AREAS.

WE ALSO HAVE A NUMBER OF OTHER PROJECTS IN WHICH WE ARE COOPERATIING WITH DOD. AS AN EXAMPLE, THE DEPARTMENT OF DEFENSE HAS A PROJECT TO EXAMINE THE COMMERCIAL PRODUCTION OF GUAYULE RUBBER FOR MILITARY USES SUCH AS AIRCRAFT TIRES AND TANK PADS -- BOTH OF WHICH REQUIRE NATURAL RUBBER. SINCE WE ALSO HAVE A GUAYULE RESEARCH PROGRAM UNDER THE CRITICAL AGRICULTURAL MATERIALS ACT, WE HAVE BEEN ABLE TO ASSIST DOD IN THIS PROJECT. AND, WE ARE PRESENTLY WORKING WITH THE ARMY TANK COMMAND AND TEXAS A&M UNIVERSITY TO SUPPLY THE ARMY WITH PROCESSED GUAYULE RUBBER. WE ARE INTERESTED IN GUAYULE FROM THE STANDPOINT OF IT BEING A POTENTIALLY PROFITABLE AGRICULTURAL CROP. WE ARE NOW DISCUSSING WITH DOD THE POSSIBILITY OF OUR TAKING AN EVEN MORE ACTIVE ROLE IN THIS PROJECT.

WITH REGARD TO OUR RELATIONSHIPS WITH EXTRAMURAL RESEARCH PERFORMERS. AT USDA, THE PRIMARY RESPONSIBILITY FOR SUCH RELATIONSHIPS IS DELEGATED TO THE COOPERATIVE STATE RESEARCH SERVICE, AND THE ADMINISTRATOR OF THAT AGENCY, DR. PATRICK JORDAN, HAS PROVIDED YOU WITH DETAILED INFORMATION REGARDING THIS RELATIONSHIP. FROM THE TIME OF ABRAHAM LINCOLN, THIS NATION HAS RECOGNIZED THE TALENTS AND ABILITIES OF OUR COLLEGES AND UNIVERSITIES. TODAY, WITH THE ADVENT OF BIOTECHNOLOGY, WE ARE WITNESSING AN INTENSIFICATION OF THAT INTEREST.

THE BIOTECHNOLOGY INITIATIVE OF USDA WAS AIMED AT EXPLOITING SCIENTIFIC OPPORTUNITIES FOR AGRICULTURE AT ALL ELIGIBLE INSTITUTIONS AND LABORATORIES THAT HAVE THE CAPABILITY TO PERFORM BASIC RESEARCH ON AGRICULTURE-RELATED PROBLEMS. THIS COMPETITIVE PROGRAM, WHICH WAS SUPPORTED BY THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY, HAS GENERATED A GREAT DEAL OF INTEREST THROUGHOUT THE COUNTRY. AND, IN RECENT MONTHS, WE PROPOSED REVISIONS TO THE RESEARCH FACILITIES ACT WHICH WILL ALLOW INSTITUTIONS -- LAND GRANT AND NON-LAND GRANTS -- TO COMPETE FOR FUNDS ON A MATCHING BASIS FOR THE ACQUISITION OF NEW FACILITIES AND EQUIPMENT. SHOULD CONGRESS CONCUR IN OUR REQUEST FOR REVISIONS TO THE ACT, WE INTEND TO BASE OUR FUNDING DECISIONS ON TWO FACTORS: WHETHER OR NOT THE PROPOSED FACILITY WILL BE USED IN ADDRESSING NATIONAL AND REGIONAL RESEARCH PRIORITIES, AND UPON THE FINANCIAL COMMITMENT TO THE PROJECT EXPRESSED BY THE STATE.

WE ARE ALSO CONCERNED WITH THE NEED TO UPGRADE THE PROGRAMS AND FACILITIES OF OUR NATION'S HISTORICALLY BLACK COLLEGES AND UNIVERSITIES. FOR THE PAST FOUR YEARS, IN COOPERATION WITH THE CONGRESS, $40 MILLION HAS BEEN PROVIDED TO THESE INSTITUTIONS FOR THE PURPOSE OF UPGRADING OF RESEARCH FACILITIES.

OUR COOPERATIVE RELATIONSHIP WITH THE PRIVATE SECTOR IS ALSO RECEIVING A GREAT DEAL OF ATTENTION. DR. KINNEY HAS DESCRIBED THE ARS' TECHNOLOGY TRANSFER PROGRAM AND I WILL BRIEFLY CITE JUST A COUPLE OF EXAMPLES OF SUCH COOPERATIVE EFFORTS: LAST MARCH ARS EXECUTED AN AGREEMENT WITH GENEX TO PARTICIPATE IN THE DEVELOPMENT OF A VACCINE FOR COCCIDIOSIS, A POULTRY DISEASE. AND, ARS IS PRESENTLY PREPARING TO SOLICIT ON A COMPETITIVE BASIS FOR A PRIVATE SECTOR PARTNER TO DEVELOP A SIMPLE TEST FOR TRICHINOSIS IN SWINE.

MR. CHAIRMAN, IF THERE IS ONE AREA OF GREAT CHALLENGE IN THE AGRICULTURAL RESEARCH SYSTEM, IT IS IN THE AREA OF OUR RELATIONSHIP WITH THE PRIVATE SECTOR. HISTORICALLY, THE PRIVATE SECTOR HAS BEEN RELUCTANT TO EXCHANGE BASIC RESEARCH INFORMATION WITH THE GOVERNMENT SIMPLY BECAUSE THE GOVERNMENT COULD NOT GUARANTEE THAT A PRODUCT DEVELOPED AS THE RESULT OF SUCH RESEARCH WOULD NOT BE "IN THE PUBLIC DOMAIN."

CONDITIONS ARE CHANGING -- TODAY WE CAN ISSUE EXCLUSIVE LICENSES TO PRIVATE SECTOR COMPANIES TO DEVELOP AND MARKET PRODUCTS WHICH HAVE BEEN INVENTED BY GOVERNMENT SCIENTISTS.

WE HAVE GENERAL KNOWLEDGE ABOUT PRIVATE SECTOR RESEARCH ACTIVITIES -- AND THE PRIVATE SECTOR IS GENERALLY WELL AWARE OF USDA RESEARCH. BUT THERE ARE SEVERAL PROJECTS IN THE PRIVATE SECTOR WHICH ARE AKIN TO "TOP SECRET" AND TO WHICH WE HAVE NO ACCESS. AS AN EXAMPLE OF SUCH A PROPRIETARY PROJECT, TWO FIRMS HAVE BEEN PARTICIPATING IN A PROJECT UTILIZING THE NASA SPACE SHUTTLE.

WE LEARN THROUGH THE NEWS MEDIA THAT THESE FIRMS HAVE BEEN ABLE TO CREATE USABLE QUANTITIES OF A TOP-SECRET HORMONE TO BE SEPARATED FROM A BUFFER SOLUTION -- SOMETHING WHICH IS DIFFICULT TO DO ON EARTH. THIS IS AN EXCITING DEVELOPMENT, ONE WHICH MAY HOLD GREAT PROMISE IN THE DEVELOPMENT OF DRUGS. ONE CAN SURMISE THAT THE PRIVATE SECTOR HAS MILLIONS OF DOLLARS INVESTED IN THIS PROJECT AND HAS LITTLE INTEREST IN ALLOWING COMPETITORS TO GAIN ACCESS TO IT.

THERE HAVE BEEN SEVERAL PIECES OF LEGISLATION PROPOSED WHICH WOULD ALLOW GOVERNMENT LABORATORIES TO ENTER INTO LIMITED PARTNERSHIPS WITH PRIVATE SECTOR FIRMS AND INSTITUTIONS. WE WOULD WELCOME SUCH AN OPPORTUNITY AND BELIEVE SUCH RELATIONSHIPS WOULD BE MUTUALLY BENEFICIAL. IN THIS REGARD, I HAVE WORKED CLOSELY WITH DR. BRUCE MERRIFIELD, THE ASSISTANT SECRETARY OF COMMERCE FOR PRODUCTIVITY, TECHNOLOGY AND INNOVATION.

AS TO THE RELATIONSHIP OF USDA TO THE SCIENCE AND ENGINEERING INFRASTRUCTURE, YOU POSE A NUMBER OF RELEVANT QUESTIONS.

YOU HAVE ASKED ABOUT THE AVAILABILITY OF QUALIFIED SCIENTIFIC AND TECHNICAL PERSONNEL TO MEET PRESENT AND PROJECTED NEEDS. IT IS CERTAINLY NO SECRET THAT THE NUMBER OF POST-DOCTORAL STUDENTS IN AGRICULTURE HAS BEEN DECLINING. TO CHANGE THAT TREND, WE HAVE SPONSORED A PRE-DOCTORAL GRANTS PROGRAM AIMED AT ATTRACTING OUTSTANDING SCIENCE-ORIENTED STUDENTS TO PURSUE ADVANCED DEGREES IN THE FOOD AND AGRICULTURAL SCIENCES. THIS IS A MODEST PROGRAM AND ONE WHICH MAY HAVE TO BE ACCELERATED UNLESS THE PRESENT TREND IS REVERSED. THERE IS GROWING COMPETITION FOR AGRICULTURAL SCIENTISTS. IN USDA, WE HAVE A NUMBER OF INCENTIVE PROGRAMS FOR OUR SCIENTISTS -- BONUS PAYMENTS FOR OUTSTANDING WORK, AND MODEST PAYMENTS FOR PRODUCT PATENTS. WE WILL HAVE TO BECOME EVEN MORE INNOVATIVE IN THE FUTURE IF WE ARE TO REMAIN COMPETITIVE.

I WOULD BE REMISS IF I DID NOT MENTION THE IMPORTANT ROLE WHICH IS BEING PLAYED BY OUR HISTORICALLY BLACK INSTITUTIONS IN TRAINING FUTURE SCIENTISTS. THE 1890 INSTITUTIONS, TUSKEGEE UNIVERSITY, AND THE UNIVERSITY OF THE DISTRICT OF COLUMBIA ARE ALL PARTNERS IN THE FEDERAL SYSTEM AND WE HAVE EARMARKED FUNDS FOR STUDENT DEVELOPMENT PROGRAMS AT THESE INSTITUTIONS.

WITH THE LARGE NETWORK OF RESEARCH INSTITUTIONS IN THE PUBLIC SECTOR, IT BECAME NECESSARY SEVERAL YEARS AGO TO DEVELOP AND REFINE THE CAPABILITY OF PROVIDING AN INVENTORY OF PROJECTS AND RESEARCH FINDINGS. THE CURRENT RESEARCH INFORMATION SYSTEM (CRIS) PROVIDES THAT ON-LINE CAPABILITY. THIS SYSTEM ALLOWS SPECIFIC SEARCHES BY TITLE, PROJECT, SUBJECT, AND GEOGRAPHIC AREA. I HAVE SUBMITTED TO YOU A SAMPLE COPY OF A CRIS RESEARCH REPORT. THIS ONE HAPPENS TO BE A LISTING OF ALL REMOTE SENSING PROJECTS AND IT WILL GIVE YOU A GOOD IDEA OF THE SYSTEM CAPABILITIES.

TURNING TO YOUR QUESTION RELATING TO INTERNATIONAL ISSUES, I CAN ONLY SAY THAT IN THE CONTEXT OF NATIONAL SECURITY, WE HAVE FEW CLASSIFIED PROJECTS. WE DO EXCHANGE A GREAT DEAL OF SCIENTIFIC AND TECHNICAL INFORMATION WITH FOREIGN NATIONS. HOWEVER, WE ANTICIPATE AS WE MOVE INTO NEW APPLICATIONS OF BIOTECHNOLOGY THAT WE WILL NEED TO REVIEW THIS ISSUE.

THROUGH SCIENCE AND TECHNICAL AGREEMENTS, THROUGH OTHER FORMAL AND INFORMAL AGREEMENTS, WE MAINTAIN AN EXCELLENT WORKING RELATIONSHIP WITH THE INTERNATIONAL SCIENTIFIC COMMUNITY. WE HAVE HAD SOME MINOR PROBLEMS WITH GERMPLASM EXCHANGES, BUT MOST SUCH ISSUES ARE RESOLVED THROUGH NEGOTIATIONS.

USDA'S OFFICE OF INTERNATIONAL COOPERATION AND DEVELOPMENT (OICD) DIRECTS AGENCY FOR INTERNATIONAL DEVELOPMENT AND COUNTRY-FUNDED INTERNATIONAL TRAINING AND TECHNICAL ASSISTANCE; PARTICIPATES IN THE MANAGEMENT OF USDA INTERNATIONAL SCIENTIFIC EXCHANGE AND RESEARCH PROGRAMS, AND WORKS WITH UNIVERSITIES AND AGRIBUSINESS IN INTERNATIONAL TECHNICAL PROGRAMS.

YOU HAVE SUBMITTED SOME SPECIFIC QUESTIONS REGARDING REGULATION-DRIVEN RESEARCH. USDA IS NOT PRIMARILY A REGULATORY AGENCY. HOWEVER, WITHIN USDA, WE DO HAVE SOME AGENCIES WHICH DEAL WITH REGULATORY MATTERS, SUCH AS THE ANIMAL AND PLANT HEALTH INSPECTION SERVICE (APHIS), THE FOOD SAFETY AND INSPECTION SERVICE (FSIS), AND THE FEDERAL GRAIN INSPECTION SERVICE (FGIS). THE BULK OF RESEARCH ACTIVITIES FOR THESE AGENCIES IS CARRIED OUT BY THE AGRICULTURAL RESEARCH SERVICE. FOR INSTANCE, APHIS FUNDS APPROXIMATELY $6 MILLION IN RESEARCH PROJECTS THROUGH ARS. APHIS ALSO MAINTAINS SOME LABORATORY FACILITIES FOR SPECIFIC APPLICATIONS. THIS SYSTEM SEEMS TO WORK WELL WITHIN USDA. TO PROVIDE SEPARATE RESEARCH FACILITIES FOR EACH OF THESE AGENCIES WOULD NOT BE COST EFFECTIVE.

OF COURSE, DECISIONS BY REGULATORY AGENCIES IMPACT FARMERS AND RANCHERS. DECISIONS BY THE ENVIRONMENTAL PROTECTION AGENCY OFTEN REQUIRE TECHNICAL RESPONSES FROM USDA. AS AN EXAMPLE, USDA PERFORMS BENEFITS ASSESSMENTS ON THOSE AGRICULTURAL CHEMICALS WHICH ARE UNDER SPECIAL REVIEW STATUS BY EPA. THESE REVIEWS ARE DESIGNED TO PROVIDE INFORMATION TO EPA WHICH IT CAN USE IN MAKING A FINAL DETERMINATION AS TO THE FATE OF A SPECIFIC CHEMICAL. IF, FOR INSTANCE, A CHEMICAL IS KNOWN TO HAVE ADVERSE IMPACTS ON THE ENVIRONMENT, IS THERE A SUITABLE ALTERNATIVE? WILL THE WITHDRAWAL OF THE CHEMICAL CAUSE UNDUE ECONOMIC HARDSHIP ON THE AGRICULTURAL COMMUNITY? ARE THERE ALTERNATIVES TO OUTRIGHT WITHDRAWAL, SUCH AS PESTICIDE APPLICATOR TRAINING PROGRAMS, SPECIFIC USE ALLOWANCES AND SUCH? SUCH STUDIES ARE BEST DONE BY USDA BECAUSE WE HAVE THE INFORMATIONAL NETWORK NEEDED TO EXTRACT SUCH DATA.

IN ALL INSTANCES WHERE USDA RESEARCH IS PRODUCED FOR REGULATORY AGENCIES, WE DO ATTEMPT TO ISSUE RESULTS IN A FORM WHICH CAN BE READILY TRANSLATED BY THE REGULATORS. AND, RESEARCH SCIENTISTS OFTEN INTERACT DIRECTLY WITH REPRESENTATIVES OF THE REGULATORY AGENCIES.

THE FINAL SUBJECT WHICH YOU ADDRESSED INVOLVES FEDERAL LABORATORIES.

DR. KINNEY GAVE YOU AN OVERVIEW AS TO THE ORGANIZATION AND ASSIGNMENT OF WORK IN THE ARS LABORATORIES. I AM WELL PLEASED WITH THE RELATIONSHIP WHICH ARS HAS HAD IN WORKING WITH THE UNIVERSITIES, INCLUDING THE SHARING OF LABORATORY FACILITIES AND PERSONNEL. I WANT TO SEE A CONTINUATION AND A STRENGTHENING OF SUCH RELATIONSHIPS IN THE YEARS AHEAD.

THE LAST QUESTION WHICH YOU POSED DEALS WITH THE POLICY TOWARD ESTABLISHMENT OF NEW FEDERAL LABORATORIES AND THE REORIENTATION OF EXISTING FACILITIES. WE MUST MAINTAIN OUR POSITION AS A WORLD LEADER IN SCIENTIFIC REASEARCH, AND THIS MEANS WILL MUST DEVOTE OUR ATTENTION TO PROGRAM IMPROVEMENTS RATHER THAN CONSTRUCTION PROJECTS.

I MIGHT NOTE THAT I HAVE ALSO SUBMITTED FOR YOUR REVIEW A COPY OF THE USDA NEEDS ASSESSMENT REPORT WHICH WAS TRANSMITTED TO CONGRESS LAST YEAR. THIS DOCUMENT COVERS IN DETAIL MANY OF THE SUBJECTS WE HAVE DISCUSSED HERE TODAY. I DO APPRECIATE THE CONTINUING INTEREST OF THE SCIENCE AND TECHNOLOGY COMMITTEE IN THE RESEARCH PROGRAMS OF USDA. THIS CONCLUDES MY FORMAL STATEMENT. I WOULD BE PLEASED TO RESPOND TO YOUR QUESTIONS.

-0-

Mr. FUQUA. Thank you very much, Dr. Bentley.
Now, we will hear from you, Dr. McDonald.

STATEMENT OF DR. FRANK B. McDONALD, CHIEF SCIENTIST, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC

Dr. MCDONALD. Good morning, Mr. Chairman.

I welcome the oppportunity to testify before the Committee on Science Policy, Task Force on Science in the Mission Agencies.

We at NASA are the Nation's mission agency for aeronautics and space research. Our goal is to maintain U.S. leadership and pre-eminence in space sciences, space technology and aeronautics.

As I see it today, the state of NASA is healthy, in space sciences in aeronautics, we are seeing right at this moment—we are approaching very rapidly an operational Shuttle, and we have taken off on a very exciting new adventure as we go out and move well along toward planning the Space Station.

The success with which we have achieved our goals in the NASA program can be traced to the very productive and effective cooperative relationships that we have nurtured and maintained over more than two decades and a half with our research partners, the universities, other Federal laboratories, nonprofit research institutions, industrial organizations and a variety of international organizations.

The diversity of NASA's scientific and technical programs require that we maintain different management approaches for science and for the development of applied research and technology in the aeronautics area. These are combined and coordinated by a coherent planning process that insures that we have an overall balanced program, and it also gives us a means of checking.

Here is our long-range program plan that we have just put out for 1986. It especially focuses on the immediate program over the next 3 years. It is a very good barometer for the next 5 years, and it gives some indication of where we think we are going over the next 10 years. This is, for us, a very useful process. It represents inputs from a great variety of sources in the space science area, from the Space Science Board of the National Academy of Sciences, from the Aeronautics and Space Engineering Board of the National Academy of Engineering, from industry, and from our own NASA Advisory Council which is made up principally of people from industry and the universities.

I will first talk about the program management in the Office of Space Science and Applications that manages and plans NASA's space science and application program. It has two principal centers that work directly for it: the Goddard Space Flight Center in Greenbelt, which is primarily our pre-eminent science center within the agency which manages most of the low orbit programs; and JPL, which is concerned with solar system exploration, Deep Space Network.

We also have very major science programs at the Marshall Space Flight Center that manages the Space Telescope. We are just planning the Advanced X-ray Astronomy Facility and other programs, and at the Ames Research Center in Mountain View, CA, where

we have a large life-sciences program, infrared astronomy and other areas.

The scientific breadth of our program is very large, extending from Earth sciences, solar system exploration, astronomy, solar and terrestrial sciences, microgravity sciences, advanced communications, and life sciences. These are closely coordinated with the other Federal agencies, particularly in the Earth sciences program, with NOAA, with the National Science Foundation and other areas, and in astrophysics with the National Science Foundation.

We can break the program down into three major catagories: the flight programs that range all the way from a very large program like the Space Telescope, Galileo, down to individual Space Shuttle payloads—these are supported, and this accounts for roughly 60 percent of the $1.6 billion OSSA budget; Mission Operations, which maintains these missions when they are in orbit, and this is where we sort of get the life blood of new results that flow into the scientific community.

We have seen an ever-increasing length of lifetime. We have the Pioneers. They are now still working after 10 years. The international ultraviolet explorer is going well after 7 years and still having a very crowded observing program.

That is—Missions Operations is a very important part of the science program, and the research base is supplied by R&A, the Research and Analysis and the Suborbital program which you put something on the order of 27 percent of the OSSA budget of $427 million. This research base is the principal support of university research, the proposal to handle standard peer review for quality and relevance. It is also the major funding source for advance mission planning, for the development of new detector technology. It supports NASA's immediate scientific goals and at the same time supports the basic science that is necessary for maintaining national pre-eminence in space science.

The typical university grant from the Research and Analysis Program is on the order of $50,000 to $125,000. These are normally funded for 3 years. They can extend up to $1 million where centers of specialized capability have grown.

The overall scientific objectives of the Space Science Programs are defined in a highly interactive process among OSSA management, the discipline chiefs who manage the various research disciplines, the Space Science Board, the National Advisory Council. This process works. I mean, if you look now as we come up with our 1986 budget, I think No. 1, we tried to establish new starts. It is the clear consensus of the vast variety of disciplines that a mission in oceanography was the first choice of what should be done now. The flight experiments themselves, for a given mission, are chosen by competitive peer review in response to an announcement of opportunity.

The Space Science Program is a national one directed from NASA headquarters. I think we may be one of the few agencies who subject our center research and analysis efforts to peer review by the outside on individual proposals, and where the centers must also compete with the outside world for the opportunities to fly on the missions. It is a very competitive program. I think that degree

of competition is one of the things that has maintained it at such a high level.

The aeronautics and space technology goal is to maintain the United States in a position of world aerospace leadership. It is based on three pre-eminent research laboratories: the Ames Laboratory in Mountain View, Lewis, and Langley. They all have broad capabilities, but they are focused to remove overlap.

The areas of specialization are established by NASA headquarters that provides the strategies, direction and resources. The aeronautics program is very closely coordinated with the needs of DOD and with industry. A significant part of that is the development of space technology for future missions: large space structures, robotics, new forms of propulsion.

Sixty percent of the space technology is conducted in-house. Forty percent goes out to universities and industry. We are shaped very much by the astronomy—by the Aeronautics and Space Engineering Board of the National Academy of Engineering and by our own in-house advisory groups.

The Office of Aeronautics and Space Technology total university runs on the order of $50 million, of which 80 percent is funded through research grants of something on the order of 700 grants per year and roughly $65,000 per grant to 160 different institutions. We also maintain six university Centers of Excellence to develop new technology that we think is going to be important, and then there is a fund for independent research that supports new and innovative technology on the order of $4 million a year at 100 grants per year.

We have also established the Office of Commercial Programs to try to enhance the commercial potential of space, and one of the first steps in doing this is to establish some five centers for commercial development at five universities at the rate of roughly $1½ million per year. This will be continued over a 5-year program. It is in very close partnership with industry, and we hope this will play a very key role in developing the potential of doing commercial activities in space.

Maintaining our scientific and engineering base, a strong supply of scientists and engineers, is extremely important to NASA. We recognize that our succcess depends very, very strongly on the competence of the people that we have working on this program. We try to encourage this.

Graduate students play an active role in many of our programs in space sciences and aeronautics. We have enhanced this with graduate student fellowships. We also try to provide postgraduate training at the NASA centers through a program of the National Academy of Sciences Residents Research Associates that take place at the nine NASA centers.

We try to encourage outreach programs, and we feel that sometimes, such as the recent program to put a teacher in space, is again, an effort to focus on how important we feel that reaching out into the elementary and secondary levels, trying to encourage people in science, mathematics, and engineering at a very early age, is important to our future and is something that we think is very important.

Thank you for this opportunity, Mr. Chairman. I will be glad to respond to any questions.

[The prepared statement of Dr. McDonald follows:]

NASA
National Aeronautics and Space Administration

Hold for Release Until
Presented by Witness

October 4, 1985

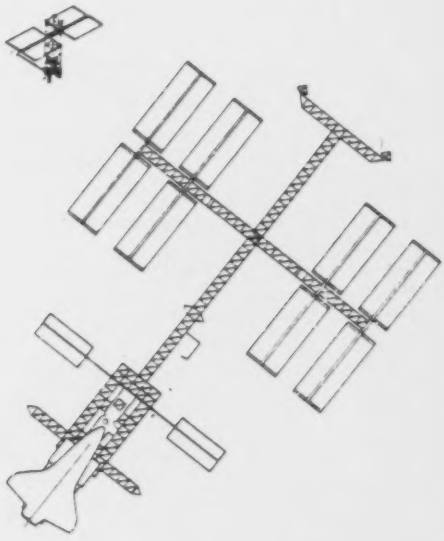
Task Force on Science Policy

Committee on Science and Technology

House of Representatives

Statement by:

Dr. Frank B. McDonald
Chief Scientist



99th Congress

Hold for Release Until
Presented By Witness
October 4, 1985

Statement of

Dr. Frank B. McDonald
Chief Scientist

National Aeronautics and Space Administration

before the

Task Force on Science Policy
Committee on Science and Technology
House of Representatives

Mr. Chairman:

Thank you, Mr. Chairman, for the opportunity to testify before the Committee's Science Policy Task Force on the important subject of "Science in the Mission Agencies and Federal Laboratories".

I am pleased to participate in today's hearings with officials from other Federal "mission agencies" and from several nongovernmental organizations concerned with the health of this Nation's basic and applied research programs. Much of the success which we have achieved in the NASA program can be traced to the productive and effective cooperative relationships which we have nurtured over two and one-half decades with our research partners in the universities, in other Federal laboratories, in nonprofit research institutions, in industrial organizations and in a variety of international organizations. In my testimony today, I would like to highlight some important characteristics of the working relationships which have evolved over time making it possible for NASA to conduct highly-complex technological missions involving such disparate institutions.

The wide diversity of NASA's scientific and technical programs require different management approaches for science and for the development of applied research and technology. These different management approaches are combined and coordinated by a coherent planning process that ensures the overall NASA program is a balanced and forward looking one.

This planning process begins with an annual review by NASA management of proposed programs for both the prospective year and for later years. These proposals from NASA's program offices at Headquarters have been refined with the assistance of management

at NASA's centers and NASA's advisory committees. The advisory apparatus includes the Boards of the National Academies of Science and Engineering and the Committees of NASA's Advisory Council, as well as leaders in industry, universities and nongovernmental research organizations. This process is of great value not only for setting goals and policy on a continuing basis, but also for providing a measure of progress in fulfilling NASA's overall mission.

The responsibility for program definition, as well as the management, of NASA's basic and applied research is concentrated in NASA's Office of Space Science and Applications and in the Office of Aeronautics and Space Technology. The following discussion focuses on the goals and objectives of their research programs and on a number of factors that are important in defining and implementing these programs, including (1) the value of NASA's relationship with extramural research performers, (2) the role of Federal mission agencies in creating and maintaining a healthy science and engineering infrastructure and (3) the role of NASA field centers in carrying out the Agency's research and technology programs. In addition, a new NASA initiative by the Office of Commercial Programs involving Industry-University-NASA research partnerships is described.

Space Science and Applications

The Office of Space Science and Applications (OSSA) manages NASA's major scientific and applications space flight programs, various research activities carried out with balloons, aircraft, and sounding rockets as well as ground-based research. OSSA has responsibility for about 20 percent of the total NASA program and has institutional management responsibility for the Goddard Space Flight Center (Greenbelt, Maryland) and the Jet Propulsion Laboratory (JPL) (Pasadena, California). JPL is operated for NASA by the California Institute of Technology as a government-owned-contractor-operated laboratory.

Goddard and JPL are the principal NASA centers for the development and operation of unmanned scientific and applications satellites and also play key roles in operating the tracking and data acquisition network for the agency. Goddard has evolved as the major center in NASA for earth-oriented satellites (including remote-sensing) and supports NOAA in the development and procurement of meteorological satellites. JPL has evolved as the major center in NASA for solar system exploration and supports this activity by operating the Deep Space Network used for communications with planetary spacecraft.

In addition to the programs at Goddard and JPL, major space science and applications projects are being carried out at the Marshall Space Flight Center (Huntsville, Alabama) (Hubble Space Telescope development and microgravity research); the Lewis Research Center (Cleveland, Ohio) (advanced communications satellite technology and microgravity science); and at the Johnson Space Center (Houston, Texas), and the Ames Research Center (Moffett Field, CA) (life sciences).

The Space Science and Applications programs span a range of scientific and technical disciplines of extraordinary breadth and diversity: astrophysics, solar system exploration, solar terrestrial science, earth science and applications, life sciences, microgravity science and applications, and advanced communications satellite technology.

OSSA is organized to manage these activities through eight technical divisions which in turn are staffed with appropriate science discipline Chiefs who are expert in these particular scientific disciplines. The OSSA program falls logically into three categories:

- Flight Programs -- includes major free-flying satellites which typically require 3-7 year development schedules and several years of science operations. Total project life from conception through development, science operations, and data reduction and analysis may easily span a decade or more. Scientific satellites have grown significantly in complexity as instrument technologies have advanced. The flight program also includes space shuttle payloads.

- Mission Operations and Data Analysis (MO&DA) -- these programs provide for operational support to science missions beginning about 30 days after launch and for the duration of the planned operational mission -- normally one or two years, except for planetary missions where the flight time may be several years. Funding for data analysis may extend beyond the operational period of a spacecraft because of the time required to process and interpret experimental results.

- Research and Analysis (R&A) -- these programs provide funding for ground-based research and represent the principal source for ongoing support of science investigators at universities and other research institutions. OSSA project funding is administered through contracts and grants which total about $365 million per year. All proposals for Research and Analysis support are peer-reviewed and are re-evaluated periodically for quality and relevance. The R&A program is also a major source of funding for advanced mission planning and for advanced technical development on scientific instruments to be flown on future missions.

The scope of OSSA's programs, including the internal/external balance of these programs was clearly recognized in the report of the Space and Earth Science Advisory Committee on "Research and Analysis in the Space Sciences" (July 1984):

> "In considering the NASA science program, it must be realized that the agency has been given the responsibility for managing and fostering programs of national significance. The importance of the R&A program within NASA can be viewed from two perspectives: as directly supporting NASA's immediate scientific goals, and as supporting the basic science that is necessary for achieving long-term success in the programs in the space and earth sciences for which NASA is responsible.
>
> NASA has a distinctive role as a manager of national programs in that it must integrate contributions from three diverse communities: the universities, the NASA centers, and industry. The efficacy of the total effort depends strongly on maintaining appropriate balances between these components, taking advantage of the special strengths of each, and stimulating each of them to contribute in an optimum way to the total endeavor."

The Research and Analysis, Mission Operations and Data Analysis and a significant part of the suborbital program together comprise OSSA's "research base." This research base provides ongoing support for operational spacecraft as well as the basic infrastructure of support for the conduct of ground-based activities at the NASA centers, in the universities, and in other laboratories of the Principal Investigators and Co-Investigators who make up the core science team for space science and applications missions. A typical university research grant from the Research and Analysis program averages from $50,000 to $125,000 per year. Following a peer-reviewed selection procedure an experiment would normally be funded for three years or more. Some grants are larger, ranging up to $1 million per year in areas where centers of specialized capabilities have grown up in the universities.

Figure 1 provides a breakdown of the FY 1986 budget for OSSA showing the distribution of funds for major program elements. Figure 2 provides a similar breakdown by economic sector. As can be seen in the chart, about 80 percent of the OSSA program is extramural, representing funds spent with universities, aerospace contractors, and other supporting activities.

The scientific objectives of OSSA programs are determined through an interactive and highly iterative planning process which involves OSSA management, the discipline scientists in the OSSA program divisions and field centers, and the independent advisory committees of the National Academy of Sciences (Space Science Board). Also involved in defining program objectives and in assigning priorities are NASA's internal advisory committees organized under the NASA Council. Of these, the most directly involved in the review of ongoing programs and near-term planning are the Space and Earth Science Advisory Committee, the Space Applications Advisory Committee and the Life Sciences Advisory Committee.

It is important to stress the "close coupling" of the flight program and ground-based activities in the research base: The results from successful flight projects flow backwards into the knowledge base for particular disciplines thus contributing to the definition of future science objectives and flight projects. Conversely, ground-based technology efforts supported by the research base provide the basis for enhancing scientific instrumentation thus enabling more powerful tools for future flight projects. The highly iterative nature of this planning process is illustrated graphically in Figure 3.

The distribution of the Space Science and Applications effort among NASA field centers on major hardware projects is heavily influenced by the specialized capabilities which have evolved at the various centers. From time to time specific policy decisions must be made by NASA Headquarters concerning roles and missions of competing centers as, for example, a recent OSSA decision to assign lead responsibilites for on-orbit satellite servicing to the Goddard Space Flight Center.

The relative proportion of in-house/out-of-house development efforts on major hardware projects is a consideration weighed in the "New Start" approval process, which involves a series of presentations and independent technical and cost reviews that culminate in the final decisions as to whether or not to proceed by the NASA Administrator. Project management for flight projects is usually assigned to a center, with systems development and integration assigned to a prime contractor. At times certain flight projects are developed primarily in-house in order to maintain technical skills which are critical to the center's ability to perform effectively the contractor management role which is the typical mode of project management.

The OSSA approach to assignment of flight experiment opportunities and research grants among competing scientists inside and outside of NASA may be unique in that it provides for independent peer review of all proposals including those submitted by in-house NASA scientists. The selection of

proposals received in response to an Announcement of Opportunity are carried out through formal procedures similar to the Request for Proposal and Source Selection Board rules which govern major government procurements. These regulations provide for strict confidence of information received on competing proposals and on evaluations carried out by the Space Science Steering Committee leading to final payload selection by the OSSA Associate Administrator. The objective is to assure selection of the best flight experiments that meet criteria of scientific "merit" and "relevance" to the science objectives defined in the Announcement of Opportunity. Less formal procedures are used in OSSA Headquarters to evaluate smaller research grants and contracts, but all science proposals are subjected to peer review to assure even-handed selection of the highest quality work. The Headquarters Science Discipline Chiefs play a major role in assuring the integrity and effectiveness of the selection process.

Many OSSA projects involve cooperation with foreign scientists ranging from personnel exchanges, to sharing of mission data, to development of major components of complex spacecraft. Arrangements usually entail foreign partners paying for their own instruments and other hardware developments which are contributed to the total effort. Providing launch services as a "quid pro quo" for international sharing of flight opportunities is a well-established consideration in the negotiations. Benefits from international cooperation beyond the obvious foreign policy gains include cost-sharing on expensive missions, and providing reciprocal access to first-class science and facilities between the partners. Trends toward increasingly complex and longer duration missions such as the Hubble Space Telescope -- coupled with growing interest and capabilities abroad -- suggest that international cooperation will be a common ingredient in the definition of future space science missions.

Aeronautics and Space Technology

The basic objective of the NASA Technology Research program is to provide advances for future aeronautical and space systems that will enable the U.S. to maintain a position of world aerospace leadership. The Office of Aeronautics and Space Technology (OAST) organization is founded on three preeminent research laboratories, the Ames, Langley, and Lewis Research Centers. Each center has broad capability for research across the aerospace sciences in addition to providing the major national resource in terms of both facilities and research personnel in their major areas of concentration. The centers, by mutual agreement and Headquarters concurrence, select areas of emphasis to minimize duplication of resources.

NASA Headquarters provides strategic direction and resources for the center research efforts managed by NASA centers. For aeronautics research this direction is responsive to National priorities, Congressional emphasis and technological opportunities as portrayed by the extensive system of industry/government/academic advisory committees. A disciplinary display of the FY 1986 R&T base and systems technology programs is provided in Figure 4. The space technology research program is responsive to needs and opportunities for enabling the capability of planned and forecast missions and programs. Projected system needs are compared against technological trends and forecast advancements to identify areas of opportunity for technological research and to provide the basis for the prioritization of resources. The FY 1986 R&T base and systems technology detail is provided in Figure 5.

As illustrated in Figure 6, approximately 60 percent of aeronautics research is conducted within the agency, primarily at the three research centers. The balance of the program is funded through industry contracts for applied research, and university grants for the more basic research activities. The distribution of these resources is about 70 percent for applied and 30 percent for basic research.

Recommendations of formal advisory groups and ad hoc committees heavily influence the areas of research emphasis and the attendent priorities. Expert advice and guidance is provided by the Aeronautics Advisory and Space Systems Technology Advisory Committees, the Aeronautics and Space Engineering Board of the National Academy of Engineering, and specialized ad hoc groups, primarily under the auspices of the National Academy.

The OAST university program, currently at a $50 million annual level (Figure 6) is funded through research grants, support to research institutes, the establishment of unique Centers of Excellence at appropriate universities, and through various jointly funded programs with the universities and/or other Federal agencies. These university programs characteristically address long-range, high-return and high-risk research topics. The topics and areas of research interest are made known to the university community through the conduct of topical symposia and workshops and are solicited by both formal and informal invitations for proposals.

The major portion (80 percent) of the OAST university program is funded through the research grant process. This activity is intended to extend the Agency's mainstream research in support of the OAST technology program elements. The program is delegated to, and managed by NASA's research centers and provides in the order of 700 grants per year at about $65,000 per grant to some 160 different institutions around the country.

University Centers of Excellence have been established at six universities to develop unique expertise in newly emerging fields such as composite and ceramic materials, computer sciences, and artificial intelligence. These grants average $500,000 per year per school. Jointly funded programs are being pursued with the Federal Aviation Administration to encourage graduate studies in advanced avionics and controls and to accelerate research in such areas as air traffic control and wind shear penetration modeling. Approximately 15 percent of the university program supports generic basic research. The $8 million provides for university needs in graduate and undergraduate curricula development and for the important Fund for Independent Research which is designed to encourage novel and basic investigations more fundamental and/or advanced than the focused OAST research program.

The Fund for Independent Research is managed by the research centers. About one hundred grants totaling $4 million ($40,000 average) are the result of awards to both solicited and unsolicited proposers. This program is under the cognizance of each center's Chief Scientist and a Basic Research Council of leading experts from NASA's centers. Other university programs include specialized education and training in fields such as computational fluid dynamics and aeronautics research.

NASA also participates in Federal University Programs. These include: summer employment for faculty and students; a grant program for Historically Black Colleges and Universities; an employee graduate study program; and an intergovernmental mobility program.

Each aeronautics research center publishes a Research Proposal Submission Guide defining the submittal process. The National Research Council participates in a cooperative process of publishing abstracts of NASA research needs. The centers' Joint Research Institutes serve as networks to the university community. The University Space Research Association provides another networking source of NASA research guidance. Furthermore, there are regular solicitations on both specific and broad research areas of interest that are pursued through Announcements of Opportunity or "Dear Colleague" letters.

Proposal evaluation and selection is primarily an internal process but is frequently augmented by support from university and industry specialists. Research results and products are evaluated by both center and outside peer review groups. A most productive technique has been to assemble all grantees and contractors for a review of research in areas of common interest. All grants and contracts require a final report submittal and they are published through the Scientific and Technical Information Facility (STIF). Many researchers, of course,

publish their results in professional journals and in conference or workshop proceedings. Feedback from the research community occurs both informally through contract and grant monitors and more formally through those experts that participate in the Advisory Groups previously described.

OAST has extensive involvement with foreign research counterparts through both informal and professional exchanges and through more formally established international working groups. The Advisory Group for Aerospace Research and Development (AGARD) provides an extensive basis for mutually beneficial exchanges with the Europeans in aeronautics and to some extent the broader aerospace technologies. An OAST/European Space Technology Center informal working group on technology planning serves a similar purpose for space technology interactions. Through our center's Joint Institutes, internationally recognized experts participate for up to a year as researchers in their programs. The centers also sponsor programs that enable exchange of researchers with France, Germany, Britain, and Japan.

Industry/University/Government Research Partnerships

A year ago NASA established an Office of Commercial Programs at Headquarters to contribute to the maintenance of U.S. technological leadership through increased investment by the U.S. private sector in commercial space activities. This office will encourage private sector investment by aerospace companies and other industrial entities with the potential for manufacturing in space, and facilitate private sector space activities through access to available U.S. Government capability. NASA's specific initiatives in these regards include establishing the Centers for the Commercial Development of Space and increasing the number and type of NASA facilities available for private sector use in space. For both these initiatives, NASA requires documented private sector investment to the activity at the onset of the project.

The Centers for the Commercial Development of Space are new. They have been established to stimulate high technology research, development and production in the space environment. This research should eventually lead to the development of new products which either have commercial potential or contribute to possible commercial ventures. Twenty-one proposals were submitted in June 1985. These were reviewed by a group of 25 peers including 17 from the private sector. Of the 21 proposals, five were selected for funding in FY 1985: Battelle Laboratories, Columbus, Ohio; Vanderbilt University, Nashville, Tennessee; University of Alabama,

Huntsville; University of Alabama, Birmingham; and the Institute for Technology Development, Jackson, Mississippi. The Centers are unique combinations of industrial, university, and government partners and some contain up to ten industrial corporations, five universities, and substantial support from State and local governments. NASA will fund these Centers for a period not to exceed five years after which they are expected to become self-sustaining. First-year NASA support ranges from $750,000 to $1,140,000 for the Centers, and the non-NASA support is significant. Six additional Centers are planned for FY 1986. Proposals from which to make those selections are due on April 15, 1986.

The Office of Commercial Programs will also fund the development and/or fabrication of multiuser facilities to help facilitate commercial use of space. These facilities are proposed by NASA's field centers and, in addition to conceptual analysis and a project operating plan, require documented company interest in using the facilities with an indication of the amount of resources a company will commit to support their portion of the R&D activities. Facilities that have either been proposed and/or are funded include the variable temperature environmental chambers to conduct protein crystal growth experiments, multiple experiment processing furnace and the advanced automatic directional solidification furnace to conduct melt growth experiments, and the microgravity materials science laboratory at the Lewis Research Center. Approximately 50 percent of the FY 1985 budget for commercial programs supports Centers for the Commercial Development of Space, a unique university/industry/government partnership.

Maintaining the Base of Highly Qualified Engineers and Scientists

The health of the Nation's aeronautics and space research programs is directly dependent on maintaining an adequate supply of qualified scientific and technical personnel and adequately equipped facilities. NASA considers a strong, interdependent relationshp between NASA and the educational community essential to fulfilling the needs for scientific and research manpower. To this end, NASA has developed and/or utilized many programs to integrate students and faculty into the research programs of the agency.

A new and innovative program to stimulate interest in long-term research opportunities was initiated by NASA in FY 1984 with the support of the University Space Research Association. NASA assists in the formulation of credit courses at the undergraduate level for the design and exploration of advanced systems concepts for future space missions. When combined with summer internships at NASA, these courses provide insight and training for 50 young engineers and scientists.

The NASA Graduate Student Researchers Program, initiated in 1980, provides approximately 80 new fellowships each year to U.S. students pursuing either a masters or doctorate degree in disciplines related to the agency's mission. NASA also awards approximately 250 fellowships in conjunction with the American Society for Engineering Education to U.S. citizen university faculty to conduct research during the summer at the NASA centers.

The NASA Resident Research Associateship Program, administered through the National Research Council, provides opportunities for approximately 200 postdoctoral scientists and engineers to perform work of their own choice which is compatible with the research interest of NASA. For recent doctoral graduates the program provides an opportunity for concentrated research in association with selected members of the NASA laboratory staff, often as a climax to formal career preparation.

NASA's university programs provide an institutional approach to the development of strong, mutually productive relationships between NASA and the university community. Such programs aid in the development of scientific and technical personnel who become the ultimate research performers for NASA, whether they be civil service, university faculty or industry.

Mr. Chairman, that concludes my testimony. Thank you for inviting NASA testimony today.

Figure 1

OFFICE OF SPACE SCIENCE AND APPLICATIONS

RESEARCH AND DEVELOPMENT

FY 1986 BUDGET REQUEST

(DOLLARS IN MILLIONS)

$1613.2M

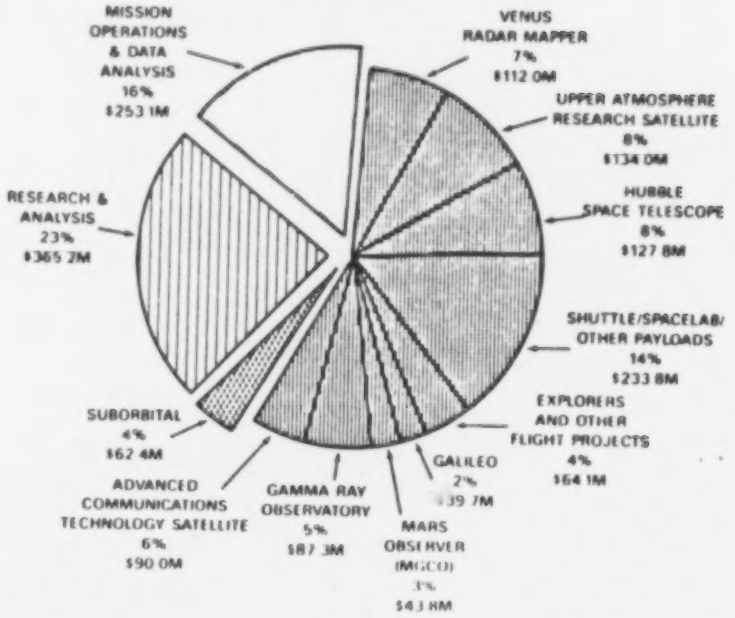

MISSION OPERATIONS & DATA ANALYSIS 16% $253.1M
VENUS RADAR MAPPER 7% $112.0M
UPPER ATMOSPHERE RESEARCH SATELLITE 8% $134.0M
HUBBLE SPACE TELESCOPE 8% $127.8M
SHUTTLE/SPACELAB/ OTHER PAYLOADS 14% $233.8M
EXPLORERS AND OTHER FLIGHT PROJECTS 4% $64.1M
GALILEO 2% $39.7M
MARS OBSERVER (MGCO) 3% $43.8M
GAMMA RAY OBSERVATORY 5% $87.3M
ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE 6% $90.0M
SUBORBITAL 4% $62.4M
RESEARCH & ANALYSIS 23% $365.2M

Figure 2

OFFICE OF SPACE SCIENCE AND APPLICATIONS
DISTRIBUTION BY ECONOMIC SEGMENT
FY 1986 BUDGET REQUEST
(DOLLARS IN MILLIONS)
$1613.2 M

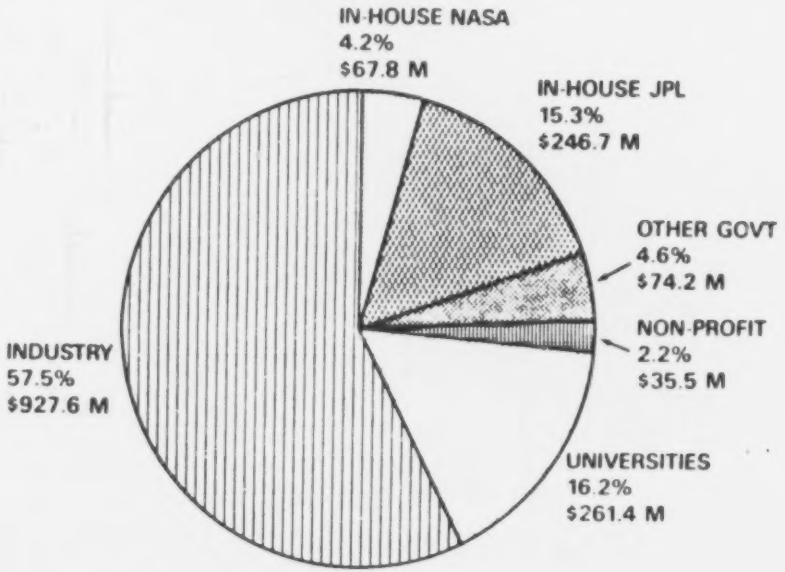


Figure 3

NASA PLANNING PROCESS

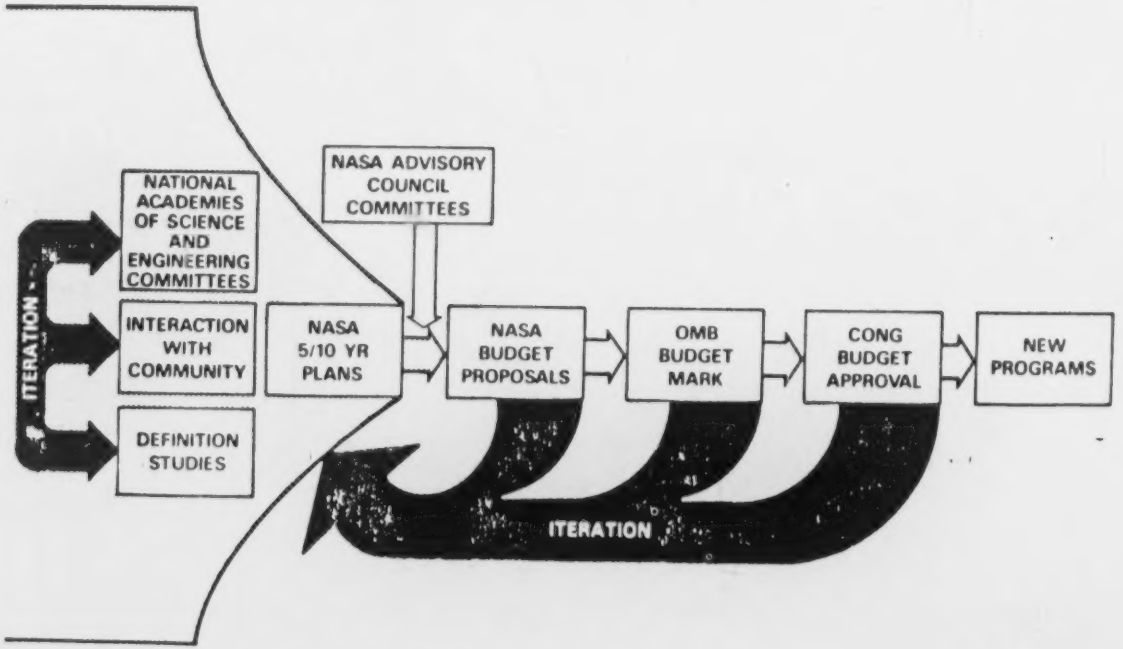


Figure 4

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

AERONAUTICS RESEARCH AND TECHNOLOGY

FY 1986 BUDGET REQUEST

(DOLLARS IN MILLIONS)

$ 354.0 M

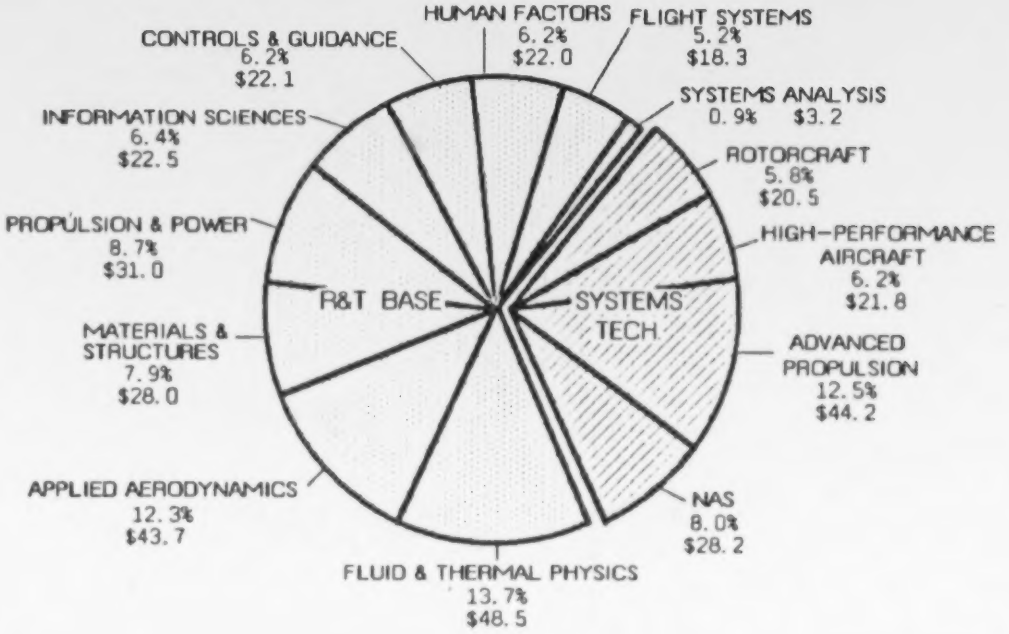


Figure 5

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

SPACE RESEARCH AND TECHNOLOGY

FY 1986 BUDGET REQUEST

(DOLLARS IN MILLIONS)

$160.0 M

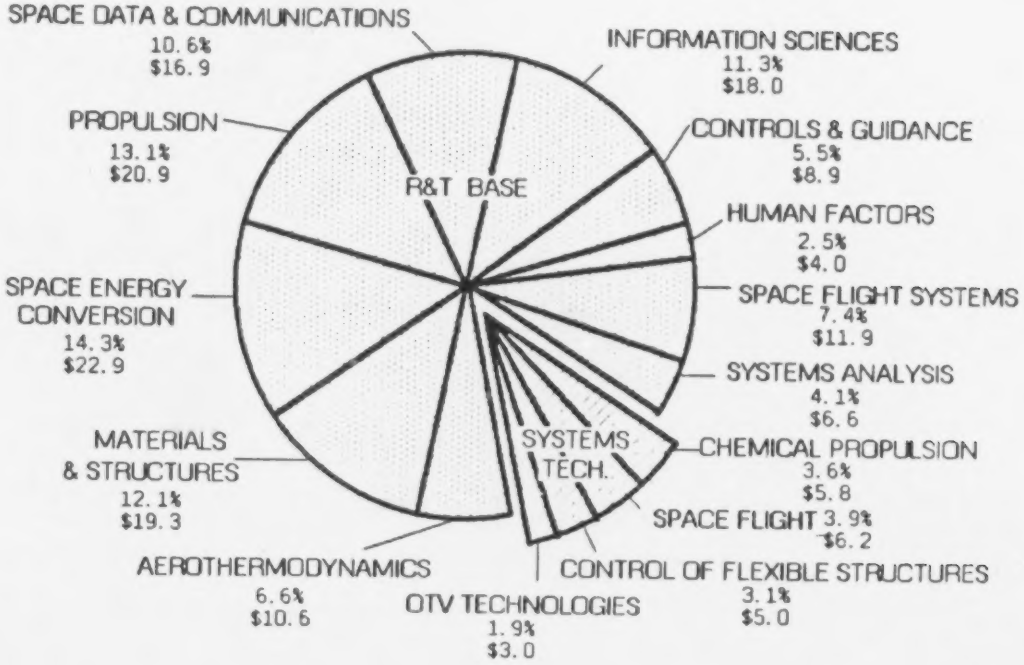


Figure 6

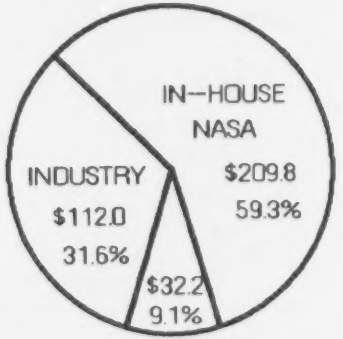
OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

DISTRIBUTION BY ECONOMIC SEGMENT

FY 1986 BUDGET REQUEST

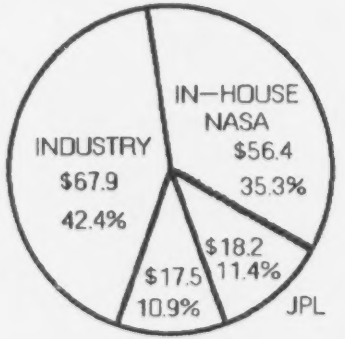
(DOLLARS IN MILLIONS)

AERONAUTICS



TOTAL $354.0

SPACE



TOTAL $160.0

Mr. FUQUA. Dr. McDonald, I know on the last page of your prepared testimony, you said in the prepared statement that approximately 80 new fellowships each year go to U.S. students pursuing masters or doctors degrees. How many all total do you have? Is that new students or is that——

Dr. MCDONALD. That has only been in our fellowship program which was very, very strong in the 1960's. We have only had that in operation 1 year, so we have on the order of something like 50 students, and we hope to grow that to 80. Our goal is to build that up to a modest program on the order of 200 students a year.

Mr. FUQUA. Very good. Dr. Bentley, yesterday we got in with Dr. Kinney and Dr. Jordan about advisory committees and so forth, and I know the two agencies that are sitting on either side of you, DOE and NASA—DOE has the ERAB committees that advise them which are outside people.

NASA has the Space Science Board and other advisory——

Dr. MCDONALD. And the ASEB——

Mr. FUQUA. Outside groups. I was noting in the green book, on the back page you had the advisory committee. If my calculations are correct, there are 31 people. They are not counting the Executive Secretary of which 12 of these, almost half, come from within the hierarchy of the Department of Agriculture here in town, and all of the rest are associated with Agricultural Experiment Stations and so forth, or research facilities, and very few come from industry or from outside or scientists that may not be in the administrative end of that.

Do you think you get the right input from these advisory groups? Of course, in the case—I will let them defend or condemn their boards, and I am not being critical. I am only asking a question, because that is what we are trying to find out here. It seems like this limits the amount of outside interaction that can come into play, particularly in some of the broad policy issues that the Department might be interested in or should be intersted in.

Dr. BENTLEY. Mr. Chairman, I would like to elaborate a bit on this advisory group. This is sort of the top group that was established by Congress to be the coordinating and oversight as far as planning.

You are recognizing the way it operates. That is that there are within a whole series of groups that represented commodities, groups who might, say, have research committees, cattle, citrus industry, and poultry, and so forth, have a whole labyrinth of committees that advise on this, and these kinds of recommendations are made by the user, producers and scientists that are associated with those particular areas. And their recommendations flow into the research committee and ultimately get incorporated into the recommendation or are given consideration in the recommendations as they emerge from the overall joint council.

In addition to that, within the experimental stage——

Mr. FUQUA. It is kind of a filtering system.

Dr. BENTLEY. Yes. Every State has some type of an advisory committee, and sometimes they are rather extensive within States that deal with plant pathology or with products, agriculture, so forth,

and then the Agricultural Experiment Stations themselves have a series, have some advisory groups where they call on scientists.

In the Competitive Grants Program we have a very active and excellent science advisory committee, and then within the Agricultural Research Service, they, too, have a series of committees that give them advise on water technology and so on.

So, we think we are getting that. On the other hand, I think it is an area of such scope and such importance that we are looking for better ways to achieve this.

In fact, I am very pleased that I have as my deputy Mr. Dan MacPherson who is here this morning, and who has had a career with a major food company, General Mills, and has retired from that position and has been willing to assume decisional responsibilities and serve in this, and that is part of the reason I am delighted is he will provide a decisional link for us with the industrial sector.

Mr. FUQUA. Dr. Trivelpiece, how do you find advisory committees who are trying to bring forth areas of science policy that they think, particularly within that field, to the attention of the people in DOE and your particular case?

Dr. TRIVELPIECE. I think they are indispensable. It depends on the precise circumstance which is involved. In some cases, in fields such as high energy physics, the High Energy Physics Advisory Panel plays a very key role. That is more or less a closed group, and we need the advice from them on what they regard as the priorities within their own program area; what would we be doing in order to try to make advances in that field. And then it ranks from that to what I call a down and technically intensive type of advisory functions. There are several of those, the Nuclear Science Advisory Committee and so on.

It ranges from those to the one you mentioned, the Energy Research Advisory Board which is the highest level advisory comittee in the Department and reports directly to the Secretary. It consists of about 26 members who are chosen broadly for their national leadership characteristics and so on, and they look across the Department as a whole and try to provide what I would call up-and-out advice—that is, where should the Department be going globally in its overall mission activities in science and energy and national security? They tend to look at things from time to time of a specific technical nature.

For example, the Fusion Advisory Committee is technically intensive and advises the program on specific technical directions; as reviewed by a separate committee within ERAB on the fusion program—the one in ERAB was to look at the program as a whole and where it is going in the national context.

So, it is an indispensable function within the Department to use these advisory committees, and there is not a fixed simple formula by which they are used. But it depends on the circumstance, and I think they are very well tailored to our needs. That includes things like the Petroleum Council, and the Coal Council as well, which tend to be larger bodies that look at the industry as a whole.

Mr. FUQUA. Dr. McDonald.

Dr. MCDONALD. I think they can be a pain. They can be a headache and they sometimes tell us things we don't want to hear, but I

think they are absolutely invaluable, particularly in the space science area.

If we look at the Space Science Board—and what isn't generally recognized is that the real work of the Space Science Board is done by a very extensive network. I think there is some eight program committees.

Gene Levy, who will testify later this morning from the University of Arizona, was head of the complex, the Committee on Planetary Exploration, and it is these committees who really get in and sort of chart out our future in the space science area.

I think they have done a truly outstanding job in trying to give us advice and guidance, and part of the problem is they have filled our plates with things that will keep us busy for the next 10 years, and we have trouble doing it all, but we do need them.

Mr. FUQUA. One of the questions that came up yesterday, and I think Dr. Kinney mentioned it, was that one of the advantages of having a GOCO lab was the fact that the freedom that the operator of the lab, whether it be the university consortium or others, would have an opportunity to try to retain and keep some of the stars and superstars.

I know DOE—I think exclusively all of our labs are operated as GOCO's, with few exceptions.

Department of Agriculture is probably GOGO's, and NASA with the exception of JPL is the only one that comes to mind right now.

Dr. MCDONALD. That is the only one, yes.

Mr. FUQUA. Maybe this is addressed to all three, but particularly to you, Dr. McDonald and Dr. Bentley. Not necessarily that they have to be a whole structure changed to become GOCO's, but how can we operate the GOGO labs—that is Government-owned, Government-operated, for anybody that is not familiar with all this lingo that goes on around here—so that we could retain some of the top people. I know the Naval Research Lab is operated in that same fashion. It appears to me that there is a great opportunity or possible great opportunity in, particularly NASA, and USDA, for some improvement, and maybe through congressional- acts in trying to free up some people or free the regulations and maybe the bureaucratic impediments in trying to retain the top flight people that you need in some of those areas.

Maybe you would like to comment.

Dr. MCDONALD. Yes, I think we are particularly proud of the vigor and the excellence of the eight GOGO labs that we have. That doesn't mean they can't be improved. We are studying in line with the Packard report——

Mr. FUQUA. This is what I am referring to.

Dr. MCDONALD. Right. The various ways one might change the system, and I think it can range all the way from converting to GOCO's to much simpler changes that would simply change the compensation packages and would make it possible to put together packages to keep both vigorous management and keep—attract and keep the sort of all-stars in both engineering and science.

So, I think in the long run that is going to become a serious problem, and it will need to be addressed.

Dr. BENTLEY. Dr. Kinney pointed out we have a limited number of these arrangements, and so far they have been identified with

management of a facility that is located on the university campus is a good example of that, and where it would be—there is an existing establishment that can take over that responsibility, and there is a shared concern about the goals and functions of those labs.

I think that the problem as I understand it so far in the administration—I don't know the details, but one of them is that the matter of accountability—how do you delegate and agree on an operating plan? But then there is a kind of an accountability that comes to the agency that almost says that they have to have absolute oversight almost day by day sometimes, and that makes it a little difficult. Sometimes, if we work on those we will have to find a mechanism that can delegate greater responsibility to the person operating the facility.

That is one of the questions, and then some of the other employment practices that have to be transmitted to the university, say, makes it difficult for the university to comply with its own set of regulations and those that affect Federal funding programs.

Mr. FUQUA. I am thinking not necessarily a university operating—we have Dr. Trivelpiece in the Department of Energy—the University of California is operating several of the labs, but there are several that are operated by a consortium of universities, which are separate from the management of the university.

Dr. BENTLEY. Yes, sir.

Mr. FUQUA. And that was what I was referring to, if that were feasible?

Dr. BENTLEY. I think though that kind of arrangement would be feasible. I don't recall right now of a one except part of our laboratory that we are talking about on genetic suppression laboratory that we call it for a short name, at the University of California at Berkeley as part of our western regional laboratory. There we have a joint venture that we do involve other universities in programmatic development, not necessarily management in the program, and we think that has a great deal of appeal to us. We could go to a consortium of universities or organization to operate a laboratory.

I guess in agriculture it is somewhat different in terms of our tradition, say, than it is in energy. Energy laboratories, it is my recollection some of them are in the newer areas, so whereas the laboratory in agriculture in Peoria, the people in the lab in Peoria, utilization of the laboratory has its origin with a specific groups and organizations that see that laboratory with some proprietary sense that they are associated with it and maybe make if a little more difficult for——

Mr. FUQUA. In other words, the proposed change may not play well in Peoria?

Dr. BENTLEY. Right. You have helped me make or illustrate a point.

Now, so we would have to look at those in a little different way. We have industry relationships with most of these, look to it if it is a Federal laboratory, they feel that the Federal Government or the Federal Government through the ARS should operate that laboratory. But I certainly am not opposed to looking at the opportunities for this because of that—the statement that you made earlier that we have to think about new relationships to accommodate changes

taking place in science and nature of activities and I guess the whole area of molecular biology and biotechnology is pressing it, compressing the time frame that we can do these. Where we have gone at more leisurely pace prior to these kind of development it is coming in more rapidly, and I think very it is very exciting because I think it opens new opportunities for us.

Mr. FUQUA. Did you want to comment?

Dr. TRIVELPIECE. One of the concerns is that what are those functions in science and technology for which being a government employee is an essential characteristic and to look at that and then decide perhaps that other things, other areas could be done under contract and subcontract modes. There are things which the Department has which we do regard being essentially in environmental measurement laboratory. Upper New York is populated by Federal laboratories.

So there are functions that are essential and perhaps should be looked at in that light. It isn't necessary that everybody be a Federal employee in the science arena. That would permit a salary arrangement different from that which is presently involved.

Mr. FUQUA. Most of the agencies have separate offices within your agency breakdown that support extramural research. If I were an individual researcher and wanted to apply, is there a central office somewhere that I could go and find out or get on the mailing list or find out where I might apply for a research grant, or do you have to go to all the different people that handle that extramural research?

Dr. BENTLEY. I would respond yes, there is a central office and its notification process for the competitive grants, which are really investigator driven type of requests, although they do involve an institutional dimension as well. There is a central office for making application time scale.

With regard to the State Agricultural Experiment Stations, the actual grants, the grants are made on a block grant basis to the States and that then is the subject of the allocation to projects would be done at a State by State level, by the State Agricultural Experiment Station director. Then in the Agricultural Research Service, where there are grants or agreements and so forth, those are initiated more through institutional arrangements. For example, in the area of water—in the water research there is an effort to create a program at a university that might be worked more through the university director to have an Experiment Station. So, yes, there are specific locations and it is identified. We attempt to reduce the confusion as to that issue as much as possible.

Dr. MCDONALD. I think we use it as a performance test to try to find the right place in NASA as to where one should go. We don't make it particularly easy, particularly as we do have two different lines. The aeronautics and space science area, I think the process actually—there is also an office of university programs which, if you go to that, they will sort of almost immediately direct you to the right door. If one makes contact with our Office of Space Sciences and Applications, or with the Office of Aeronautic and Space Technology, I think you can immediately sort of get directed to the right office where you can get the required information. So we don't, as I said in the opening statement, we don't, we really have

several lines of business that we are in, and our relations with the extramural partners are handled in a different way by those organizations. We think in each case it is more efficient and so I think the system is a good one, but I myself constantly get calls by people who want a new experiment or new technology and we direct those to them. So I think the system works and works well in our particular case, without having a central function.

Dr. TRIVELPIECE. There isn't a simple central, organized office within the Department that handles this, because of the broad diversity of things in which the Department is involved. There is a networking system of information that causes most people to know more or less with reasonable accuracy where to begin applying and are directed to the right individual in terms of proposals. But things appear in the Federal Register in some circumstances and other circumstances Commerce Business Daily—a program opportunity for where it will be competitive bid. Unsolicited proposals sometimes end up in the wrong in-box and by an informal communication with the network in the Department, they eventually end up in the right one. Not necessarily do they all get funded. They end up being reviewed in the right place.

Mr. FUQUA. Dr. Bentley, since your department—I am not referring to you—the Department of Agriculture is probably the great grand daddy of all of——

Dr. BENTLEY. Almost true.

Mr. FUQUA. Of all the activities here, I am trying to think of 20 to 40 years down the road, and management and the way things are done. If you, without thinking about it, OMB and all the other things, but if you could rewrite the acts of the Morrill Act and Hatch Act and Evans-Allen, and McIntire-Stennis and all the others, to take effect at the year now, or year 2000 or past the year 2000, what long-range needs do you see in agriculture research and ways to achieve those in the modern society that we live in?

Dr. BENTLEY. Mr. Chairman, that is a big question. Let me give you my view, some impressions that I would have.

First, I would say that turning to the fundamental philosophy, I see a great deal of merit in the Federal-State system that we have had over the past century and so I would preserve that concept.

Now, getting out to how you would implement it, I believe that to do this there needs to be some funding on the Federal side, in terms of grants.

I would look though to some consolidation under two, perhaps three major headings. One, I would think in the formula grants or block grants I would attempt to reduce the number of units or boxes so to speak, that funds came in. You listed various activities. They are all related, they are all carried out in institutions. I would try to think in terms of one major set of block grants. That would give a great deal of autonomy to the university or the cooperator in using these funds and that there could be through agreement and prior discussion, priorities reflecting the activities that come together in a book such as this, or we might want to expand it or change it. I would have that. The other major part, I would maintain a formula block grant concept for assuring a capacity of our country to do this kind of activity.

The second part that I think there is a need for a competitive peer review and more investor-initiated kind of activities. We have a Competitive Grants Program now. You have been familiar with the experiences we have had over the years to get to where we are today in the acceptance of this by research communities. I see some. I would talk about considerable expansion there to focus in on high priority research areas and the application of science to our food, fiber, and nutrition system.

The third part of the activity—and perhaps I should say there are four parts to it—the third part I think that the Department of Agriculture has not been as active in providing funding on some types of, on a matching basis or for high priority needs areas for facilities and state-of-the-art equipment that is needed to accommodate the changes that are taking place in science and technology and their application to universities.

There has been a—much has been done, but I think we are moving as you give time horizons of 10 or 15 or 20 years, I think we are going to need that. For that reason I mentioned the facilities bill as a section within the 1985 farm bill as an example.

Then I believe that the Department of Agriculture should have a clearer mandate in support of scientists. That is, the development of scientists in particular. As I see it, the Federal enterprise and do the business in at the graduate level or postdoctoral level of developing the kind of expertise and facilitating the development of expertise.

And I would think that we should have a longer term commitment here that would make it possible for the Department to do things that would be more parallel to the comments made by my colleagues this morning, in other parts of the Federal Government where they have been able to do more in the development of scientists and so on.

Those are four areas that come to mind. I would want to be sure though that as we talk about expanding the program, I am thinking about looking at our natural resources and getting detailed information. I am talking about water and soil preservation and nutrition and diet health areas. I am making a very broad statement. I am not trying to delineate it to the scope of things, because of the importance of our food and fiber system to our people and to our economy.

Mr. FUQUA. And particularly on petroleum-based products?

Dr. BENTLEY. Yes, sir.

Mr. FUQUA. Pesticides and fertilizer and all of those?

Dr. BENTLEY. Yes, sir. I suspect that, if I may add an additional one, the matter of science as it relates to agriculture is the same as it is for all of our other sciences. That is, we have to think in terms of the international dimensions and we are in a global society in terms of science and in terms of agriculture, and weather I think that is well known by many segments of agriculture. But still many people feel that our system is highly domestically oriented and that there is science in other parts of the world, scientific developments are taking place everywhere and U.S. agriculture has to be a part of this.

Mr. FUQUA. Mr. Volkmer.

Mr. VOLKMER. I would like to ask Dr. Bentley. My understanding of the answer to the chairman's question regarding the changes to be made would be basically that you wouldn't change the research base that you are presently using in the system, Federal-State relationship that you are presently using—that you may use to rearrange the method that system operates as far as funding.

Dr. BENTLEY. Yes, sir.

Mr. VOLKMER. That is correct?

Dr. BENTLEY. Yes, sir, Mr. Volkmer, I would feel this way because I am so convinced of the concept and philosophy we have. But we could streamline the system of how we fund it, and then not have to spend as much time as we do on some of the parts of it. Because when, in the final analysis it is done by people and institutions that are committed to doing this work, I think we could probably spend less time on those activities and talk more about priorities and directions for research, responses to problems and so forth.

Mr. VOLKMER. I have no further questions.

Mr. FUQUA. Thank you, gentlemen, very much for joining us this morning. We appreciate your contributions.

Dr. BENTLEY. Thank you. We appreciate being here.

PANEL 2: MISSION-AGENCY SUPPORTED EXTRAMURAL RESEARCHERS

Mr. FUQUA. Our second panel will consist of those policies and relationships from the point of view of the mission agency performer. They include Dr. William F. Miller, president and chief executive officer of SRI International; Dr. Eugene H. Levy, Lunar Planetary Laboratory, department of planetary science, University of Arizona in Tucson; and Dr. Marvin E. Ebel, associate dean, graduate school, University of Wisconsin in Madison; and George H. Dummer, director, office of sponsored research, Massachusetts Institute of Technology.

Dr. Miller, we will begin with you.

[A biographical sketch of Dr. Miller follows:]

DR. WILLIAM F. MILLER

William F. Miller, Ph.D. is the President and Chief Executive Officer of SRI International. SRI is an independent, non-profit institution whose activities range from management consulting to scientific research. As president of SRI and an internationally known speaker, Dr. Miller has focused attention on the need for stimulating innovation and revitalizing industry by building on the nation's technological and entrepreneurial strengths.

Dr. Miller was educated as a physicist at Purdue University where he received his Ph.D. in 1956. His career history includes experience in high-energy physics, computer science, university administration and as a business consultant and venture capitalist. He joined Stanford University in 1965 as head of the Computation Group at the Stanford Linear Accelerator Center. In 1970 he was appointed Vice President for Research and in 1971 became Vice President and Provost. He became the first Herbert Hoover Professor of Public and Private Management in Stanford's Graduate School of Business in 1979. He is currently professor of Public and Private Management and of Computer Science at Stanford.

Writer, lecturer, educator, executive, venture capitalist, businessman, investor, managment consultant, nature and travel photographer, Dr. Miller is a Fellow of the Institute of Electrical and Electronics Engineers and the American Academy of Arts and Sciences. He was recently appointed as a member of the National Science Board of the National Science Foundation.

Dr. Miller currently serves as a Director of Varian Associates, Pacific Gas and Electric Company, Fireman's Fund Insurance Company, First Interstate Bancorp, and First Interstate Bank of California. He was founding partner of the Mayfield Fund.

STATEMENT OF DR. WILLIAM F. MILLER, PRESIDENT AND CHIEF EXECUTIVE OFFICER, SRI INTERNATIONAL, MEMO PARK, CA

Dr. MILLER. Mr. Chairman, before I begin my testimony, I want to say as many of our predecessors on the earlier panel did, that we certainly applaud the effort of this committee in examining science and technology. There are a lot of immediate and pressing issues that our Nation faces not only in the leadership of Government, but in the long-range education.

Now, turning to my own testimony, SRI International is a not-for-profit research and consulting organization. We have about 2,800 people worldwide, 500 Ph.D.'s, and 1,200 Masters degrees, which means really about two-thirds of our staff are professional and professional performers—about one-third is the support staff. We work purely on a contract basis and we are entirely self-supporting, and by that I mean that we have no endowment, we have no subsidies. We have to really scramble around for our work, we are very competitive in that regard, and that would distinguish us from other producers, if you like.

We are different from industry, we are different from a national laboratory, we are different from the university in that regard, and in many ways, we see ourselves as sitting between universities and industry and bridging that gap in between.

Of the revenue of SRI International, in 1984, we did about $194 million of research, and this year we will go over about $210 million. About 55 percent of the revenue comes from Government agencies. The majority of that is from the mission agencies, such as Defense, HSS and NASA. We also do work for other agencies, the National Institutes of Health, National Science Foundation, and we do work for States, regional governments, city governments and for foreign governments.

Our commercial clients include most of the Fortune 500 companies, as well as major financial institutions and industrial organizations throughout the world. We do have a world view, very global view, and it is that global view that helps us with American companies to compete globally.

Our main laboratories are located in Menlo Park, CA, though we also have offices worldwide—in 12 other countries, other than in the United States.

Now, we are larger than most of the not-for-profit research institutes, but we are very similar in character. We provide a unique and useful bridge between research and commercial phases of new technologies. We do that in many areas. So some of the smaller not-for-profits are much more focused on single subject areas, whereas we have a very broad multi-disciplinary focus at our institute. There are a number of others similar to us. I have submitted for the record the annual reports of others like ours, but I am going to talk principally about SRI and what we do, because that is what I know best, and I can speak about what we do better than what they do.

Overall, the not-for-profit research institutes as identified by the National Science Foundation, receive about $785 million annually for Federal research and development. Roughly, a third of this is in the basic research area, which means that we perform about 8 percent of the basic research for the Nation.

The institutes vary from the specific focus that you mentioned to the broad and multi-disciplinary ones, such as SRI. SRI covers the full spectrum. About 20 percent of our research is basic research by any kind of measure. Most of the support comes from either our own internal support or from NIH and from the National Science Foundation—the more basic research agencies.

So about 20 percent is basic research, about 10 percent is really pure commercialization—where we really develop a commercial product which some companies put into manufacturing and practice. We don't do manufacturing but we do the product design, and the development of it, and then someone else manufactures it. And there are several good examples of that. For example, the Savin copiers that are sold in the United States have been designed by SRI, manufactured, by Rico in Japan, marketed by Savin in this country.

We do that in drugs. We develop drugs for drug companies. We will sometimes do the testing. We do not do the manufacturing but it goes all the way to the commercial side.

This is one example of how institutes that are not-for-profit are really at their very best, is when they can take an idea from the basic research phase, all the way through to some commercial phase. You will see it all across the whole spectrum of developments. This is 20 percent basic, 10 percent commercialization. About 70 percent, the remaining 70 percent, then, is bridging the gap between basic research and commercialization.

Another way in which we feel that we are working the very best, is when we can take this broad collection of talent and capability and bring it to focus on a single company, or for that matter, sometimes on a regional, a city or Government problem. We have a process which we call innovation research where we will bring together teams of scientists, business people, engineers from across our institute to bring them to focus on the strategy and the development for a given company, a U.S. company, or for some types for a State.

We did a major study in Mid-America Trust which covered all the activities of Mid-America and how to revitalize that. We brought together talent from across the spectrum of the whole institute in doing that.

Other organizations to some degree do this. I think our breadth makes us unique. I suspect if you say you are unique you would be hard pressed to find organizations that have that kind of breadth. We have another advantage, and I suppose it was best illustrated by Henry Hansmann of Yale, who pointed out that the advantage of a not-for-profit producer is that we have both the discipline of the market, on the one hand, but that is supplemented by an additional protection given the consumer by this broader contract, that is, the organization's legal commitment to devote its entire earnings to the production of services. We have to invest our profit in the charter purposes of our organization.

We do have to make a profit. We have to make a lot of nonprofit so to speak to support our facilities and buy our own equipment and support our own internal research. But it has to be reinvested in the charter purposes of our organization. So we have that competitive aspect of the marketplace, but at the same time, the consumer has that protection knowing that we are going to reinvest what we do in their interest. We can look at things, therefore, in a somewhat broader view than publicly-held, for-profit organizations and yet a more businesslike view than that which you have in a university environment.

Now, the not-for-profits have been successful in providing solutions to a number of things that have changed the country. At SRI, for example, we developed the technology and the systems for the magnetically encoded bank checks. But not only were we able to develop that technology, but we had a business consulting group who could show the banks how to introduce that, how to develop the systems, how to utilize it after this technology had been developed.

I suppose another well-known example is the example of Battelle, where their scientists developed the copying system later known as xerography that led to the invention or patent based on which Xerox developed the copier.

Southwest Research Institute has been doing a lot in improving automobile engine efficiency and also in the efficiencies of fuels and lubricants. They have been very heavy in that part of the industrial research activity.

There are other examples that show who we can bring that variety of disciplines to bear on a single problem.

In terms of the way in which we acquire support for research, we participate in a very broad way. We participate through competitive contracts as almost any industrial contractor would. We apply for grants which are, one, in response to a general program announcement. We support technical and engineering support contracts, which are a subset if you like, of the competitive contract process.

We have a number of cooperative agreements which require cost sharing with Federally funded research and development centers and of course, we submit unsolicited proposals.

The not-for-profit institutes I mentioned cover this entire spectrum, but we account for a very small part of the total of research spending of the Federal Government. While we are more industry and business oriented than universities, we are more academic on the other hand, than research laboratories.

As the economic pressures increase, corporations, the industry and universities on the other hand are reaching into new areas of funding. The Industrial Research Institute, for instance, which represents interests of industry here in Washington, is conducting a study on how the results of federally-funded support can best be channeled into the private sector. The competition for research funding has grown, and with it there has grown demand for more efficiency.

This places an increased emphasis on the management of research, which is the quality that is at the center of the not-for-profits. Because we do have to manage ourselves well, to have a sur-

plus to reinvest in ourselves, we have to manage our research activity, we become good managers of research.

There is another change that is taking place in research. This is brought about by the change in procurements such as the Competition in Contracting Act, which has had an adverse impact in research in some ways. While indeed the drafters of the act did not intend that research should be procured on the same basis, for example, as equipment should be procured, this increased thrust for competition has produced certain notable effects, that there is a tendency to look at price rather than to look at the scientific expertise. This is most likely to have its effect on unsolicited proposals. If a program manager who is looking at an unsolicited proposal is having to think how could I show this has been competitive, it is very difficult to do. The program officer will look at unsolicited proposals and say this may be the best idea that has come around in a long time, how do I decide whether the best idea has been competitive or not? So I think it will have some tendency—certainly won't eliminate the trend or the acceptance of unsolicited proposals—but it will have some tendency to cause the program officers to be looking at the price as opposed to the scientific expertise or the quality of the idea.

In general, I would say that the basic system on which we work with the mission agencies is a good one. Their proposal solicitation is orderly, their review process for grants works very well. I believe that this area of the unsolicited proposals may not be getting enough attention. We need to get these new ideas, better ideas especially, into the mission agencies.

In a recent Rand report—Walter Baer made a report judging the quality of interdisciplinary policy research by independent research centers, he judged this on the basis off five criteria: (1) policy orientation—institutional commitment; (2) access to information; (3) independence; (4) scale and continuity of effort, and skilled personnel; and (5) incentives of performance.

On that basis, Mr. Baer found that the independent research centers rated the highest on that scale. These criteria are still valid. We believe industry and universities both moved toward the center of technology spectrum because of financial pressures, and that both will be making themselves more visible in the process.

Not-for-profit research institutes, being a smaller part of the total, have often not had visibility. We are often left out of either legislation or when agencies are thinking about the people who they should turn to, to be suppliers of their research.

That sums up my testimony, Mr. Chairman. I think not-for-profits provide a very special role in American science and technology, perhaps the best way to say it is that we organize our people as well as knowledge in a somewhat unique way.

[The prepared statement of Dr. Miller follows:]

Testimony

on

Science in the Mission Agencies --

Extramural Researchers

before the

Science Policy Task Force

Committee on Science and Technology

of the

United States House of Representatives

by

William F. Miller, Ph.D.

President and Chief Executive Officer

SRI International

October 4, 1985

Mr. Chairman, my name is William F. Miller. I am President and Chief Executive Officer of SRI International.

Before beginning my testimony, I should like to take a moment to laud the initiative of this Committee in attacking this all important issue of Science and Technology Policy. There are many immediate and pressing issues that our nation must face through the leadership of our government. But for the long term, there is no issue of greater importance to our health, welfare, and security than our policies for science and technology and the companion issue of education. The effectiveness of these policies to a large measure will determine whether we, as a nation, can compete. With wit and wisdom, we will not only compete economically, we will define the frontiers.

Now, to the testimony. SRI International is a sole-supported, not-for-profit research and consulting organization with approximately 2800 employees, of whom about 500 hold Ph.D's and 1200 hold Masters degrees. We work on a contract basis and are entirely self-supporting. Our revenues were $193.4 million in 1984 and will be over $210 million this year. About 55% of our revenue comes from government agencies, and the majority of that is from mission agencies such as the Department of Defense, HHS, and NASA. We also do work for state, local and foreign governments.

Our commercial clients include many of the Fortune 500 companies, plus major financial and industrial organizations throughout the world. Our international view helps American companies compete globally.

Our laboratories are located in Menlo Park, California. We also have offices here in Washington, D C., in New York and Chicago, as well as in 12 major cities abroad.

While larger than most of the not-for-profit research institutes, we are similar in that we provide a unique and useful bridge between the research and commercial phases of new technologies in many areas. Much of our work is done for clients in business and industry. We help move research out of the laboratory, into development and into the market-place. Thus, SRI, Battelle Memorial, IIT Research Institute, Gulf South Research Institute, Midwest Research Institute, the Research Triangle Institute, Southwest Research Institute, and the Southern Research Institute serve as technology transfer agents, synthesizing scientific developments into new applications. But we do more than that, we also assist industry in the setting of technology strategy, forecasting markets, etc. We are unique and important organizations that bridge the gap from basic research to commercial development.

Overall, non-profit research institutes, as defined by the National Science Foundation, receive about $785 million annually from the Federal government for research and development. The roughly one-third of non-profit institution R&D devoted to basic research is almost 8% of the national total.

The institutes performing this work are varied and their focus ranges from almost single concentration to those whose performance is multidisciplinary. I will submit material from the other institutes as part of my written statement. But let me describe more specifically what SRI does as a way of describing the group of multidisciplinary institutes. Approximately 20% of SRI's work is basic research, performed for government and industry. Another 10% is commercialization where we help clients in the final stages of product development. The other 70% is applications research, falling across the full spectrum, from science to the marketplace. Approximately 65% of our overall work is laboratory based.

There are two areas where we are at our best. The first is that ability I have just described; taking an idea from research to commercialization. The other is our ability to build multidisciplinary teams to solve a company's problems. We have, for instance, a standard technique called 'Innovation Search' which brings our scientists, engineers, analysts, economists and management experts together to identify new business opportunities for a client.

Other organizations do this to some degree, from universities to major corporations. However, to quote Henry B. Hansmann in the Yale Law School Review, "The advantage of a non-profit producer is that the discipline of the market is supplemented by the additional protection given the consumer by another broader 'contract', the organization's legal commitment to devote its entire earnings to the production of services." We must reinvest our excess of revenue over expenses in the Charter purposes of the Institute.

Thus, we can look at things with a broader view than would a publicly-held "for profit" company with its short-term, quarterly earnings focus, yet with more business-like view than that of the university environment. We can set up two screens for an idea, one to prove the technology and the second to prove its marketability.

Not-for-profit institutes have been very successful in providing solutions which have positively changed American society. At SRI, for instance, we not only developed the technology and the system of magnetically encoding bank checks, but also were able to help the banking industry implement the changes necessary to make that technology an accepted and useful part of our everyday lives.

At Battelle, perhaps the best example is how their scientists took a concept for copying documents and moved it from basic research to commercialization. The final product, now known as Xerox, has been quite successful.

Southwest Research Institute has been doing much to improve automobile engine efficiency and the efficiencies of fuels and lubricants.

As these examples illustrate, the capability to bring a variety of disciplines to bear is a special strength.

From the standpoint of U.S. government mission agencies, that capability is important. Not only do we provide scientific and technical competence on an "as-needed" basis--thereby reducing the need for permanent government staff, but then we also provide a broader, more complete view of the societal and business impact of a technical issue.

With that introductory positioning, let me address some specific aspects of our involvement in mission agency research programs.

The manner in which we participate is quite broad. Projects are initiated through:

- competitive contracts, as with any industrial contractor in the procurement process
- grants, won in response to general program announcements
- technical and engineering support contracts, which are a subset of the competitive contract process
- cooperative agreements, which require cost sharing with federally funded research and development centers (FFRDC) that are wholly captive to specific mission requirements and
- unsolicited proposals.

In the past, the various competitors for mission agency research dollars were more compartmentalized. Industry used its manufacturing and productive skills in performing specific contracts which were at the application end of the technology spectrum. Universities tended to the opposite end, focusing on basic research. Other participants clustered around either research or commercialization.

Not-for-profit research institutes covered the entire spectrum, understanding the complete process, but accounting for a very small part of the total research spending by the Federal government. While more industry and business-oriented than universities, we have been, and are, more academic than commercial research laboratories.

Today, as economic pressure increases, corporations and universities are reaching out to new areas for funding. The Industrial Research Institute, for instance, which represents the interests of industry here in Washington, is conducting a study on how the results from federally supported research can best be channeled to the private sector. The competition for research funding has grown and with it the demand for efficiency. This places increased emphasis on the management of research which is a quality that lies at the center of not-for-profit research institutes.

Within the government, competition for funding has also increased. There is also a demand for more efficient utilization

of each research dollar. As a result, the focus of the mission agencies has become more and more specific. Recent changes in procurement, such as the Competition in Contracting Act, have had an adverse impact on research in some ways. While drafters of the Act did not intend that research should be procured on the basis of price rather than scientific expertise, the thrust to increase competition has produced that result to a noticeable extent. Furthermore, despite exceptions to the Act for the procurement of unsolicited research proposals, the agencies are contracting for fewer of those innovative researcher-originated ideas. In the short term, agencies may find some economic relief from this situation, but in the long run, it will hurt U.S. science. This is not to say that there aren't efficiencies to be gained in the funding process, or that all research should be done "sole source". However, funding research should be viewed differently from procuring a product, as it usually is in industry.

Another change that has come about in the search for a more efficient use of research dollars is that the number of competitive procurements is going down while increasing in size. Today, the dollar value is higher and the scope of procurements is much broader. This broader scope almost demands the formation of team relationships between program participants. Naturally, that shows up in higher bidding costs to cover more complicated project coordination. The effect of this is to actually raise the cost of research, to get less science for the dollars.

What is needed? Before addressing that, let me say that the basic system under which we work with the mission agencies is a good one. Proposal solicitation is orderly. The review systems most agencies have for research grants work well. In contracts, reporting schedules are adequate. One might question the increasing complexity of safety and quality assurance regulations, since they tend to add to the price of research and are unnecessary for good researchers. They are intended to prevent bad data but raise project cost.

Long range research planning input to the mission agencies is rather informal and has always been seen as a part of the continuing dialog between researchers and agency personnel. However, we need a better forum for the setting of technology priorities. While many of the not-for-profits' management and experts participate on boards and commissions, presenting new ideas and concepts, the discussion is informal in many ways. It would be useful to have a more formal research information and planning structure--not to rigidly assign tasks--but to uncover new ideas, to provide input.

While the not-for-profit institutes account for a very small--less than 2%--part of the overall research and development activities of the United States, the impact over the years has far outweighed their size. In the years ahead, we will continue to cover the technological spectrum from laboratory to marketplace, applying a true multidisciplinary capability to the solution of problems. We will also continue to provide a unique training ground, an environment where young scientists can see the interplay of theory and practice.

I am forcefully reminded of how good we are at that every time a corporate raider hires away some of our bright young people. We fulfill an important post-doctoral and post-graduate training function. Additionally, we have a large number of graduate students from nearby universities working at SRI.

In the RAND Corporation report "Interdisciplinary Policy Research in Independent Research Centers", Walter Baer judged interdisciplinary research by five criteria:

(1) policy orientation--institutional commitment

(2) access to information

(3) independence

(4) scale and continuity of effort, and skilled personnel

(5) incentives for performance.

Using a scale from 0-10, with 10 the highest, Baer found that independent research centers rated highest, followed by industry, government and universities.

These criteria are still valid. Industry and universities have both moved towards the center of the technology spectrum because of financial pressure and have both been making themselves more visible in the process. The not-for-profit research institutes, facing similar pressure, can no longer remain in the background. Because we fall in the middle, Congress and the mission agencies often overlook us in legislation and in the promulgation of regulations. Yet, the not-for-profit research institute has a unique value in meeting the changing needs of society.

One observer summed it up very well when he said, "The not-for-profit research institute is better able than a university department to generate knowledge which is reliable and timely or requires the coordinated and protracted work of many people. Perhaps it would be better to say that institutes have found new ways of organizing--not knowledge, but professional people."

Thank you.

Mr. VOLKMER (acting chairman). Thank you very much, Mr. Miller.

Dr. Levy.

[A biographical sketch of Dr. Levy follows:]

DR. EUGENE H. LEVY

Born May 6, 1944 in New York City. Public school in New York City and Fair Lawn, N.J., graduating high school in 1962. Bachelor of Arts, high honors in Physics, Rutgers University, 1966. Doctor of Philosophy, Physics, University of Chicago in 1971.

Married to Margaret Lyle Rader, 1967; 3 children. Residing in Tucson, Arizona since 1975.

Present position: Professor & Head, Planetary Sciences Dept., Director of Lunar and Planetary Lab., University of Arizona. Also Faculty of Appl. Math. Teaches graduate and undergraduate courses.

Research and Publications: Theoretical cosmical physics, planetary physics, solar and space physics, magnetohydrodynamics. Generation and behavior of magnetic fields in natural bodies, including Earth, the Sun, and planets; origin of geomagnetic reversal; theory of cosmic rays; formation of the solar system. Techniques for the discovery and study of other planetary systems.

Previous Positions: Res. Physicist, Kodak Physics Lab., 1966; Teaching Asst., Dept. of Physics, Univ., of Chicago, 1966–1969; Res. Asst., Dept. of Physics—Enrico Fermi Inst., Univ. of Chicago, 1969–1971; Fellow, Dept. of Physics and Astronomy, Univ. of Maryland, 1971–1973; Asst. Prof., Physics & Astrophysics, Bartol Res. Foundation, Franklin Inst., 1973–1975.

Awards, Honors, Societies: NASA Fellow, Univ. of Chicago, 1966–1969; Theoretical Physics Fellow, Univ. of Maryland, 1971–1973; Phi Beta Kappa; Sigma Xi; Am. Astron. Soc.; Am. Phys. Soc.; Geophys. Un.; Int'l. Astron. Un. NASA Distinguished Public Service Medal, 1983. Res. grants from NSF & NASA.

Other Activities: Consulting and adv. panels, including member of Nat'l Acad. of Sci. Space Sci. Bd., Chair of Comm. on Planet and Lunar Enpl.; NASA Space Sci. Adv. Subcomm. & Solar Sys. Expl. Comm., 1980–1983; Comet Halley Sci. Work. Grp., 1977; Comet Mission Rev. Comm., 1980; U.S. Delegate to U.S.-Soviet Joint Work. Grp. on Near-Earth Space, Moon, & Planets; Head of U.S. Delegation to Nat'l Acad. of Sci.-European Sci. Found. Joint Working Group on Coop. in Planet. Expl., 1982–83; NASA Solar Sys. Expl. Management Council 1983–85; Congressional OTA Panel on U.S.-Soviet Sci. Coop.; NASA Space and Earth Sci. Adv. Comm., 1985–88. Scientific Consult., Rockwell Int'l. Corp. 1980. Distinguished Visiting Scientist, Jet Propulsion Lab. of the Calif. Inst. of Tech.

Address & Telephone: Office: Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721 [(602) 621–6962].

STATEMENT OF DR. EUGENE H. LEVY, PROFESSOR AND HEAD, DEPARTMENT OF PLANETARY SCIENCES; AND DIRECTOR, LUNAR AND PLANETARY LABORATORY, UNIVERSITY OF ARIZONA, TUCSON, AZ

Dr. LEVY. Mr. Chairman and members of the committee, I am pleased to be invited before this committee to discuss with you matters of national science policy. I believe that our examination of U.S. science policy is indeed timely. Vigorous scientific research is crucial to our national interest. And I do not believe that present policies are sustaining many U.S. scientific activities and capabilities in a way that meets the long-term interests and needs of our Nation.

My remarks this morning are based on my experience as a research scientist over some 15 years and as a university department head and director of a major research laboratory devoted to the space and planetary sciences.

The role of the universities and the mission agencies—let me begin by making some remarks about the special role of universi-

ties in our Nation's overall scientific research structure. I believe that the universities play an especially valuable role in U.S. science. The scientific enterprise involves several activities.

First, of course, is the conduct of research itself—the generation of new knowledge and understanding, and the invention of techniques to utilize and exploit knowledge.

Second is the propagation of knowledge throughout the society. The teaching of relatively large numbers of technically trained individuals who may do little or no research but who apply existing knowledge to the solution of society's myriad problems.

Third is the organization, preservation, and transmission of accumulated knowledge from generation to generation.

And fourth is the training and apprenticeship of the next generation of research scientists, those who will carry on into the future and generate yet more new knowledge and understanding.

Uniquely among the research institutions in U.S. science, the universities carry out all of these crucial functions. Moreover, the universities' contribution is more than the mere sum of these parts. There are symbiotic effects. I believe that the assembly of these four important activities in universities generally results in each of the functions being carried out more effectively than it might be in isolation.

I do not want to minimize the contributions of either the national laboratories, or applied and industrial research centers. However, in my view, the combination of research and teaching, the organization and preservation of knowledge, and the apprenticeship of young scientists that occurs daily in our universities provides the primary source of vigor and success in U.S. science.

I raise this issue early in my remarks to make the point that I believe that the health of the university research enterprise is essential to the health of U.S. science and technology—and by immediate extension, to the vigor and competitiveness of our Nation as a whole. It follows, therefore, that the health of the university research and education endeavor in this Nation must be a central concern of any wise national science policy. And the health and vigor of university research and education must be a central concern of all Federal science agencies—the mission agencies and the nonmission agencies alike.

Alas, it is my strong impression that this has rarely been the case in recent years. Indeed, on several occasions I have been told by congressional staffers as well as by agency officials, that the health of university research, per se, is not a concern of NASA, that it is not part of the NASA mission. I am less familiar with the other mission agencies, but I assume that similar attitudes prevail in those also. I cannot emphasize enough, as a scientist and as a citizen of our Nation, how shortsighted an approach I believe this is to the future of our society.

Of course, such shortsightedness has not always prevailed. In the early 1960's, our Nation undertook to ensure a scientific infrastructure of research facilities and research personnel, along with a vigorous program of scientific projects. During the time when the National Aeronautics and Space Administration was being founded, efforts were exerted by the Federal Government to enable a steady pace of scientific project parts, to encourage the training of a large

and effective cadre of young scientists, and to provide adequate modern scientific facilities and equipment for the conduct of research. I think it is few of today's leading space scientists who were untouched by those wise programs. Indeed, speaking for myself, I received my graduate education with a federally-sponsored fellowship and I have spent almost my entire career working in research facilities constructed under Federal programs more than 20 years ago. I believe that the past 20 years have been remarkable for the advances in science and technology paced by the United States. I also believe that this rapid pace of advance is due in large measure to the enlightened Federal science policies of the 1960's.

To the large extent, I believe that we are still living off the fruits of those enlightened policies of the early 1960's. What I mean is that those enlightened policies of the early 1960's. What I mean is that: U.S. research programs are still housed in the same physical plants, which are in many instances becoming inadequate; it is widely recognized that research equipment in the United States is growing increasingly obsolete, and too few of the scientists who have come of age during the past 10 to 15 years, after the policies changed, have been able to build research careers because of the lack of adequate research opportunities.

It seems to me that this situation—with the Nation's facilities continuing to age, with U.S. scientific equipment falling further into obsolescence, and with the presently active cohort of scientists aging while insufficient numbers of younger colleagues follow them in stably established careers with adequate research opportunities—is very deleterious to our national interest.

Recently there have been some small steps in the right direction, giving evidence at least that the problem is starting to be recognized. Last year NASA instituted a very small program of research fellowships for university graduate students. This indicates some recognition of a critical need to encourage young people into productive scientific careers. Unfortunately, I am not aware that any funds were appropriated to support this program, and I believe that, as a result, the funding involved a set-aside from other programs. To the extent that this fellowship program was funded by setting aside moneys from elsewhere in the basic research program, this is no solution at all. I do not believe that moving funds around within the already-strapped basic research programs is a useful response to the funding of fellowships; nor do I believe that such set-asides would be a useful response to the other problems of rebuilding the U.S. scientific infrastructure.

I also regard the small instrumentation-refurbishment program recently started by the Department of Defense as a step in the right direction. The vast oversubscription of this program is another piece of evidence that research equipment shortage and obsolescence is becoming a crisis in the United States. So far, however, no program has been brought forward that is of sufficient scope to make a big impact on the Nation's overall needs in research equipment.

NASA's science program, which runs at about 15–20 percent of its total budget, consists of several components which can be usefully identified. These include construction and operation of space missions and associated activities—the largest part, by far, of the

science budget—advanced technology development for future missions, and basic research activities. Much of the direct funding for research in our Nation's universities come from the last category: The so-called basic research and analysis activities; the largest part of NASA's science budget, the actual development, construction, and operation of spacecraft projects, goes largely to industry and national laboratories.

The relationship between basic space science research and the spacecraft missions is a close one. On the one hand, much of the basic research is intended to be in support of the objectives of the spacecraft program. On the other hand, the spacecraft program is largely responsive to the goals established by the scientific community as a result of the continuing basic research activities. Formally these goals, and the plans to realize them, are set through an extensive advisory process involving a broad cross section of the Nation's scientists, and reporting under the aegis of either NASA as the in-house committee, or the National Academy of the Sciences, as independent external committees. The Nation's universities are well represented in all of these councils.

Generally speaking, it is my view that this approach to the setting of programmatic goals has been effective. Many scientifically excellent and important projects are always in the hopper waiting to be implemented. Indeed, this process has been too effective in that a far larger number of projects than can be accomplished at the present rate are waiting, as potential new starts, a situation which has now been severe for nearly a decade.

One of the truly astonishing examples of the lethargy in the pace of our Nation's new starts in space science projects is the lack of a U.S. spacecraft mission to Comet Halley. The failure of the United States to respond to the appearance of Comet Halley—an event of not only deep scientific importance, but also of social and historical significance—must denote a turning point in our perception of U.S. scientific and international leadership.

A considerable amount of detailed planning for a mission to Comet Halley, was done throughout the late 1970's. Initial plans were for a mission far more capable than any within the reach of Europe or the Soviet Union. Yet here we are, just months before Comet Halley passes through the inner solar system: Japan has a modest spacecraft on its way to fly near Comet Halley; the European space agency is sending a space probe deep into the heart of the comet; and a literal parade of international scientists is lined up under the banner of the Soviet Union, with instruments on two Soviet spacecraft headed to encounter the comet.

The United States, in the meantime, sits on its figurative hands. For the most part, U.S. scientists in universities and elsewhere, are excluded from the main action of a major scientific challenge and opportunity. Fortunately, there are other comet opportunities. NASA has plans for an encounter with Comet Wild 2. But it now looks as if we may continue to sit on our national hands and pass up this one also.

Although these last several sentences about the U.S. Comet Halley debacle seem like a digression from my main point, they are in fact not a digression. All components of the space science program, space flight missions, advanced technology development, and

the so-called research and analysis activities are essential to vigor of space science in the Nation and the Nation's universities.

The relatively small number of spacecraft flight opportunities during the past decade has had a large effect on the profile of the space science experimental community. There is a startling absence of young scientists age 30 to 40 who have been able to establish space experimental research groups in the past decade. I can point to at least one important area of experimental space science in which practically the entire U.S. population of experienced practitioners will retire within the next few years. This is entirely a result of the absence of space flight opportunities.

I am to address here certain detailed, structural aspects of the mission agencies programs as they relate to universities. There are many important secondary issues with which I could deal. For example, the deluge of paperwork and niggling bureaucratic detail which encumbers so many activities and accomplishes nothing. However, I do not believe that these detailed structural questions can be isolated from the overall level and vigor of U.S. research programs in space. The fundamental structural problems in university space research and space science related national infrastructure derive from the diminished vigor of our national programs. In order to solve these problems will require:

An increase in the pace of space flight projects, both major ambitious projects and smaller projects that be done rapidly and relatively inexpensively. These would engender important fundamental science and would provide a path into experimental space science for young investigators.

An increase in the basic research and analysis programs, refurbishment of research equipment, and research and development on new experimental techniques for space science. This would rebuild and invigorate the university research and advanced training programs, and it would also encourage and support young scientists early in their careers.

Before stopping, I want to relate two personal anecdotal incidents which I believe are representative of the larger problems that I have discussed. Among the most pressing of the issues that face us in grappling with U.S. science policy is, I believe, the question of defining the appropriate level of budgetary support. How, indeed, do we determine whether our programs are adequate to our needs?

Certainly one approach is to ask whether the present program is resulting in the training of sufficient numbers of young American scientists.

Recently, I advertised an opening for a postdoctoral research associate to work in my research program at the University of Arizona. I received a reasonably large number of applications for the position. Most of the qualified applicants were foreign nationals. None of the top three applicants were U.S. citizens. Now, from my prespective as a scientist, this is immaterial. But from the Nation's perspective, this may be indicative of a potential serious problem.

It should not matter that so many of our graduate students are from other nations. After all, the United States was largely populated in this manner, and has a long record of having its population enriched by the peoples of other lands. But things are not

working out so nicely. There are few continuing opportunities for these students in the United States. Indeed, the reason for diminished interest in scientific careers among young American students is the paucity of long-term career opportunities, and this affects foreign nationals who would like to build scientific careers here even more than it affects U.S. citizens. To a large extent, what career opportunities do exist involve classified work in the defense sector and foreign students are largely barred from such positions. So in the end, we are cutting our Nation's future off, both from the vigorous, potentially productive minds among our own young people and from the bright young minds abroad. In my view, it is unwise to continue on this course.

One final personal remark builds on this point. Nine years ago I was appointed to my first high-level national advisory committee for space science. At the time I, and a few of my colleagues, were the youngest scientists in the Nation serving on such space science advisory committees. Last summer, at a meeting of a large number of advisory panels for space science, involving some 100 scientists under the auspices of the National Academy of Sciences, I noticed that I still seemed to be practically the youngest in attendance. An informal survey by several colleagues nearly confirmed that impression. There were, in fact, one or two slightly younger panelists present, but only by a couple of years.

These are anecdotes. But they point up the fact that there is a paucity of young scientists beginning their careers in a number of important scientific disciplines—not an absence, mind you, but a paucity to a degree that I believe is alarming. A national science policy should ensure that our society's needs are met with respect to the production, propagation, and utilization of knowledge, and with respect to the production of new cadre's of young scientist for the future. These are, in my view, the goals of an effective relationship between the science agencies and the universities. My experience suggests to me that present policies are deficient in both respects.

Unfortunately, there are no unequivocal measures against which we can judge these things. Decisions in these areas of policy require a measure of sense and wisdom. We either judge wisely and benefit, or we judge unwisely and suffer for it in the long run. I am encouraged that this committee is examining the issues.

Thank you for your attention. I will be glad to discuss these matters further or to try to respond to other questions you may have.

[The prepared statement of Dr. Levy follows:]

Remarks to the

COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

NATIONAL SCIENCE POLICY HEARINGS
Science in the Mission Agencies:
Relationships with Extramural Researchers
The Universities

October 4, 1985

Eugene H. Levy, Professor
Head, Department of Planetary Sciences
Director, Lunar and Planetary Laboratory

University of Arizona
Tucson, Arizona 85721

Statement of Eugene H. Levy

Mr. Chairman and members of the committee:

I am pleased to be invited before this committee to discuss with you matters of national science policy. I believe that your examination of U.S. science policy is indeed timely. Vigorous scientific research is crucial to our national interest. And I do not believe that present policies are sustaining many U.S. scientific activities and capabilities in a way that meets the long-term interests and needs of our nation.

My remarks this morning are based on my experience as a research scientist over some 15 years and as a university department head and director of a major research laboratory devoted to the space and planetary sciences.

I have been asked to focus on the role of mission agencies in the conduct of U.S. science in universities. In terms of dealing with mission agencies, my own experience--as a scientist and as a department head and laboratory director--has been greatest with the National Aeronautics and Space Administration. The National Science Foundation is another agency with which I have had considerable experience. To the extent that my remarks refer to specific experience, they will be based largely on my experience with NASA. In addition, because I am speaking in terms of my experience, rather than on the basis of detailed surveys or statistical research, I will relate my impressions, derived largely from what I see happening in the space sciences.

The Role of the Universities & The Mission Agencies

Let me begin by making some remarks about the special role of universities in our nation's overall scientific research structure. I believe that the universities play an especially valuable role in U.S. science. The scientific enterprise involves several activities:

-- First, of course, is the conduct of research itself: the generation of new knowledge and understanding, and the invention of techniques to utilize and exploit knowledge.

-- Second is the propagation of knowledge throughout the society: the teaching of relatively large numbers of technically trained individuals who may do little or no research but who apply existing knowledge to the solution of society's myriad problems.
-- Third is the organization, preservation, and transmission of accumulated knowledge from generation to generation.
-- And fourth is the training and apprenticeship of the next generation of research scientists, those who will carry on into the future and generate yet more new knowledge and understanding.

Uniquely among the research institutions in U.S. science, the universities carry out all of these crucial functions. Moreover, the universities' contribution is more than the mere sum of these parts. There are symbiotic effects. I believe that the assembly these four important activities in universities generally results in each of the functions being carried out more effectively than it might be in isolation.

I do not want to minimize the contributions of either the national laboratories, or applied and industrial research centers. However, in my view, the combination of research and teaching, the organization and preservation of knowledge, and the apprenticeship of young scientists that occurs daily in our universities provides the primary source of vigor and success in U.S. science.

I raise this issue early in my remarks to make the point that I believe that the health of the university research enterprise is essential to the health of U.S. science and technology--and, by immediate extension, to the vigor and competitiveness of our nation as a whole. It follows, therefore, that the health of the university research and education endeavor in this nation must be a central concern of any wise national science policy. And the health and vigor of university research and education must be a central concern of all federal science agencies--the mission agencies and the non-mission agencies alike.

Alas, it is my strong impression that this has rarely been the case in recent years. Indeed, on several occasions I have been told--by congressional staffers as well as by agency officials--that the health of university research, per se, is not a concern of NASA: that it is not part of the NASA mission. I am less familiar with other mission agencies, but I

assume that similar attitudes prevail in those also. I cannot emphasize enough, as a scientist and as a citizen of our nation, how short sighted an approach I believe this is to the future of our society.

Of course, such short sightedness has not always prevailed. In the early 1960's, our nation undertook to ensure a scientific infrastructure of research facilities and research personnel, along with a vigorous program of scientific projects. During the time when the National Aeronautics and Space Administration was being founded, efforts were exerted by the federal government to enable a steady pace of scientific project starts, to encourage the training of a large and effective cadre of young scientists, and to provide adequate modern scientific facilities and equipment for the conduct of research. I think it is accurate to say that few of today's leading space scientists were untouched by those wise programs. Indeed, speaking for myself, I received my graduate education with a federally-sponsored fellowship and I have spent almost my entire career working in research facilities constructed under federal programs more than 20 years ago. I believe that the past twenty years have been remarkable for the advances in science and technology paced by the United States. I also believe that this rapid pace of advance is due in large measure to the enlightened federal science policies of the 1960's.

To a large extent, I believe that we are still living off the fruits of those enlightened policies of the early 1960's. What I mean is that:

-- U.S. research programs are still housed in the same physical plants, which are in many instances becoming inadequate,

-- it is widely recognized that research equipment in the United States is growing increasingly obsolete, and

-- too few of the scientist who have come of age during the past ten to fifteen years, after the policies changed, have been able to build research careers because of the lack of adequate research opportunities.

It seems to me that this situation--with the nation's facilities continuing to age, with U.S. scientific equipment falling further into obsolescence, and with the presently active cohort of scientists aging while insufficient numbers of younger colleagues follow them in stably established

careers with adequate research opportunities--is very deleterious to our national interest.

Recently, there have been some small steps in the right direction, giving evidence at least that the problem is starting to be recognized. Last year NASA instituted a very small program of research fellowships for university graduate students. This indicates some recognition of a critical need to encourage young people into productive scientific careers. Unfortunately, I am not aware that any funds were appropriated to support this program, and I believe that, as a result, the funding involved a "set-aside" from other programs. To the extent that this fellowship program was funded by setting aside monies from elsewhere in the basic research program, this is no solution at all. I do not believe that moving funds around within the already-strapped basic research programs is a useful response to the funding of fellowships; nor do I believe that such "set-asides" would be a useful response to the other problems of rebuilding the U.S. scientific infrastructure.

I also regard the small instrumentation-refurbishment program recently started by the Department of Defense as a step in the right direction. The vast oversubscription of this program is another piece of evidence that research equipment shortage and obsolescence is becoming a crisis in the United States. So far, however, no program has been brought forward that is of sufficient scope to make a big impact on the nation's overall needs in research equipment.

Components of a Productive Relationship

NASA's science program, which runs at about 15-20% of its total budget, consists of several components which can be usefully identified. These include construction and operation of space missions and associated activities (the largest part, by far, of the science budget), advanced technology development for future missions, and basic research activities. Much of the direct funding for research in our nation's universities comes from the last category: the so-called basic research and analysis activities; the largest part of NASA's science budget, the actual development, construction, and operation of spacecraft projects, goes largely to industry and national laboratories.

The relationship between basic space-science research and the spacecraft missions is a close one. On the one hand, much of the basic research is intended to be in support of the objectives of the spacecraft program. On the other hand, the spacecraft program is largely responsive to the goals established by the scientific community as a result of the continuing basic research activities. Formally these goals, and the plans to realize them, are set through an extensive advisory process involving a broad cross section of the nation's scientists--and reporting under the aegis of either NASA as in-house committees, or the National Academy of the Sciences as independent, external committees. The nation's universities are well represented in all of these councils.

Generally speaking, it is my view that this approach to the setting of programmatic goals has been effective. Many scientifically excellent and important projects are always in the hopper waiting to be implemented. Indeed, this process has been too effective in that a far larger number of projects than can be accomplished at the present rate are waiting, as potential new starts, a situation which has now been severe for nearly a decade.

One of the truly astonishing examples of the lethargy in the pace of our nation's new starts in space science projects is the lack of a U.S. spacecraft mission to Comet Halley. The failure of the United States to respond to the appearance of Comet Halley--an event of not only deep scientific importance, but also of social and historical significance--must denote a turning point in our perception of the United States' scientific and international leadership.

A considerable amount of detailed planning for a mission to Comet Halley was done throughout the late 1970's. Initial plans were for a mission far more capable than any within the reach of Europe or the Soviet Union. Yet here we are, just months before Comet Halley passes through the inner solar system:

-- Japan has a modest spacecraft on its way to fly near Comet Halley.

-- The European Space Agency is sending a space probe deep into the heart of the comet.

-- A literal parade of international scientists is lined up under the

banner of the Soviet Union, with instruments on two Soviet spacecraft headed to encounter the comet.

The United States, in the meantime, sits on its figurative hands. For the most part, U.S. scientists--in universities and elsewhere--are excluded from the main action of a major scientific challenge and opportunity. Fortunately, there are other comet opportunities. NASA has plans for an encounter with Comet Wild 2. But it now looks as if we may continue to sit on our national hands and pass up this one also.

Although these last several sentences about the U.S. Comet Halley debacle seem like a digression from my main point, they are, in fact, not a digression. All components of the space-science program--spacecraft flight missions, advanced technology development, and the so-called research & analysis activities--are essential to vigor of space science in the nation and in the nation's universities.

The relatively small number of spacecraft flight opportunities during the past decade has had a large effect on the profile of the space-science experimental community. There is a startling absence of young scientists--ages 30 to 40--who have been able to establish space experimental research groups in the past decade. I can point to at least one important area of experimental space science in which practically the entire U.S. population of experienced practitioners will retire within the next few years. This is entirely a result of the absence spaceflight opportunities.

I am to address here certain detailed, structural aspects of the mission-agency programs as they relate to universities. There are many important secondary issues with which I could deal--for example, the deluge of paperwork and niggling bureaucratic detail which encumbers so many activities and accomplishes nothing. However, I do not believed that these detailed structural questions can be isolated from the overall level and vigor of U.S. research programs in space. The fundamental structural problems in university space research and space-science-related national infrastructure derive from the diminished vigor of our national programs. In order to solve these problems will require:

-- An increase in the pace of spaceflight projects, both major ambitious projects and smaller projects that can be done rapidly

and relatively inexpensively. These would engender important fundamental science and would provide a path into experimental space science for young investigators.

-- An increase in the basic research and analysis programs, refurbishment of research equipment, and research and development on new experimental techniques for space science. This would rebuild and invigorate the university research and advanced training programs, and it would also encourage and support young scientists early in their careers.

* * *

Before stopping, I want to relate two personal anecdotal incidents which I believe are representative of the larger problems that I have discussed. Among the most pressing of the issues that face us in grappling with U.S. science policy, is, I believe, the question of defining the appropriate level of budgetary support. How, indeed, do we determine whether our programs are adequate to our needs?

Certainly one approach is to ask whether the present program is resulting in the training of sufficient numbers of young American scientists.

Recently, I advertised an opening for a postdoctoral research associate to work in my research program at the University of Arizona. I received a reasonably large number of applications for the position; most of the qualified applicants were foreign nationals. None of the top three applicants were United States citizens. Now, from my perspective as a scientist, this is immaterial. But from the nation's perspective this may be indicative of a potentially serious problem.

It should not matter that so many of our graduate students are from other nations. After all the United States was largely populated in this manner, and has a long record of having its population enriched by the peoples of other lands. But things are not working out so nicely. There are few continuing opportunities for these students in the United States. Indeed, the reason for diminished interest in scientific careers among young American students is the paucity of long-term career opportunities;

and this affects foreign national who would like to build scientific careers here even more than it affects U.S. citizens. To a large extent, what career opportunities do exist involve classified work in the defense sector; and foreign students are largely barred from such positions. So, in the end, we are cutting our nation's future off, both from the vigorous, potentially productive minds among our own young people and from the bright young minds abroad. In my view, it is unwise to continue on this course.

One final personal remark builds on this point. Nine years ago I was appointed to my first high-level national advisory committee for space science. At the time I, and a few of my colleagues, were the youngest scientists in the nation serving on such space-science advisory committees. Last summer, at a meeting of a large number of advisory panels for space science--involving some 100 scientists under the auspices of the National Academy of Sciences--I noticed that I still seemed to be practically the youngest in attendance. An informal survey by several colleagues nearly confirmed that impression. There were, in fact, one or two slightly younger panelists present, but only by a couple of years.

These are anecdotes. But they point up the fact that there is a paucity of young scientists beginning their careers in a number of important scientific disciplines--not an absence, mind you, but a paucity to a degree that I believe is alarming. A national science policy should ensure that our society's needs are met with respect to the production, propagation, and utilization of knowledge, and with respect to the production of new cadre's of young scientists for the future. These are, in my view, the goals of an effective relationship between the science agencies and the universities. My experience suggests to me that present policies are deficient in both respects.

Unfortunately, there are no unequivocal measures against which we can judge these things. Decisions in these areas of policy require a measure of sense and wisdom. We either judge wisely and benefit, or we judge unwisely and suffer for it in the long run. I am encouraged that this committee is examining the issues.

Thank you for your attention. I will be glad to discuss these matters further or to try to respond to other questions you may have.

Mr. VOLKMER. Thank you very much, Dr. Levy.
Dr. Ebel.
[A biographical sketch of Dr. Ebel and Mr. Dummer follows:]

DR. MARVIN EMERSON EBEL

Name: Marvin Emerson Ebel. Birth Place & Date: Waterloo, Iowa, September 23, 1930.

Address: Office: 328 Bascom, University of Wisconsin, Madison, WI 53706, 608 262-1044. Home: 910 Hampshire Place, Madison, WI 53711, 608 271-6254.

Marital Status: Married, 1960, to Barbara Ann Schuck, 4 children.

Education: 1946-47, Iowa State Teachers College; 1950 B.S., Iowa State College; 1952, M.S., Iowa State College; 1953, Ph.D., Iowa State College.

Experience: 1949-53, Teaching Assistant, Iowa State College; 1954-56, Instructor, Yale; 1956-57, Assistant Professor, Yale; 1957-59, Assistant Professor, Wisconsin; 1959-65, Associate Professor, Wisconsin; 1965- Professor, Wisconsin-Madison; 1973-75, Chairman, Physics Department; 1976- Associate Dean, Graduate School.

Fellowships: 1952-53, Research Corporation Fellow; 1953-54, NSF Postdoctoral Fellow; Niels Bohr Institute, Copenhagen; 1957-62, Alfred P. Sloan Foundation Fellow.

Consultant: 1959-73, Los Alamos Scientific Lab; 1962-64, IDA.

Memberships: AAUP; Phi Kappa Phi; Fellow, American Physical Society; Sigma, Xi.

Committees: 1981-82 University: Graduate School Administrative; Research Committee; Knapp Center Advisory; Graduate Assistant Stipends (Ch.); Physical Sciences Lab Advisory; Math. Research Center Advisory; Academic Computing Advisory (Vice-Coordinator of Computing); Faculty Advisory Committee on A-21; Academic Staff Area Review Committee (Administrative/Student Services/Library); Ad Hoc Committee on Research Opportunities; U.W. System Task Force on Conflict of Interest Rules.

Other Professional: Argonne Universities Association (U.W. delegate); Universities Research Association (U.W. delegate); CIC Research Officers (Ch.); Grant and Contract Policies Subcommittee of Council on Governmental Relations; AAU Task Force Effort Reporting.

GEORGE H. DUMMER

Director, Office of Sponsored Programs, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139. Home Address: 10 Princeton Road, Wellesley, Massachusetts 02181. Married to: Former Mary Martha Goodwin, Oil City, Pa. Children: David, 17; Steven, 15; Douglas, 13.

Educational background: Harvard College, B.S., 1948; Harvard Law School, J.D. 1949.

Military Service: U.S. Navy, 1950-1952: USS *Philip* (DDE498), Gunnery Officer; Pearl Harbor, Korea, Formosa, with 7th Fleet.

Professional experience (Pre-MIT): Ford Motor Company, Somerville Plant, 1952-1954, Public Relations Representative; University of California Scientific Laboratory, Los Alamos, New Mexico, 1955-1958: Group Leader, Personnel Relations.

Massachusetts Institute of Technology: Personnel Officer for Professional Personnel, 1958-1960; Office of Sponsored Programs (formerly Division of Sponsored Research); Assistant, Associate and Administrative Director successively, 1961-1973; Director, 1973 to present.

Outside professional activities (Past and Present): National Council of University Research Administrators; Member of Executive Committee; Chairman of Panels on University-Industry Relationships; Member of Long-Range Planning Committee; Faculty Member, Annual Meeting Workshops; Chairman. Select Committee on University-Industry Relationships (present).

Council on Governmental Relations of the National Association of College and University Business Officers; Chairman of Task Force on Graduate Student Support; Member, Subcommittee on Federal Management Developments; Member, Nominating Committee Member, Subcommittee on Grants and Contracts (present).

Engineering College Research Council of the American Society for Engineering Education; Member, Board of Directors and Secretary.

STATEMENT OF DR. MARVIN E. EBEL, ASSOCIATE DEAN, GRADUATE SCHOOL, UNIVERSITY OF WISCONSIN, MADISON, WI; AND GEORGE H. DUMMER, DIRECTOR, OFFICE OF SPONSORED PROGRAMS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE MA, ON BEHALF OF THE COUNCIL OF GOVERNMENTAL RELATIONS, WASHINGTON, DC

Dr. EBEL. Mr. Chairman and members of the Task Force on Science Policy, my name is Marvin Ebel and I am Associate Dean of the Graduate School, University of Wisconsin. I have been an active researcher for 30 years, conducting research in high energy physics, supported by the Department of Energy or its predecessor agencies. With me today is George Dummer, Director, Office of Sponsored Programs, Massachusetts Institute of Technology. We are there on behalf of the Council on Governmental Relations, an organization of more than 100 leading research universities. COGR was established to provide information to executive agencies of government with regard to policies, regulations and practices that affect university research. Together, Mr. Dummer and I will give you an idea of procedural matters, some of which assist the conduct of research and ought to be extended or continued Government-wide and some practices that hamper the conduct of research and delay technology transfer and should be discontinued.

I will address: one, cost sharing as an externally imposed constraint on a university's ability to direct its own research spending; two, Government support of university research as both an investment in solving problems critical to energy independence, agriculture, defense and space, and as a key ingredient in the development and training of scientists in these areas; and three, the importance of funding mechanisms and instruments as a means of providing innovative approaches to research.

Mr. Dummer will address how research can be enhanced by: (1) recognizing different classes of grantees and contractors; (2) providing the appropriate climate for research through administrative simplification; (3) and finally, understanding the effect of national security considerations on research at universities.

The first issue which I wish to take up is that of cost sharing on individual research projects, which may be funded either by grants or contracts. Let me make clear at the outset that I am not talking about cost sharing which is implicit in a cooperative agreement, nor am I referring to the sharing of the cost of major research instruments or facilities. In these circumstances it may be entirely appropriate from an institution to share in the cost of a joint research program, or the cost of an instrument or facility, especially when the use may involve projects outside the mission of the agency. What I am concerned about is a practice of expecting universities to bear part of the costs of specific research projects. This expectation is rarely, if ever, a matter of official agency or program policy. Nevertheless, it is all too common to find project officials who want to know what fraction of the costs of the project the university, in contrast to the agency contracting for the research, will bear. This in turn leads faculty to believe that they will be required to secure some university funding for each proposal, if that proposal is to be successful. Those of us in research administration

at universities are then requested to provide an allocation of the university's resources to a project either already supported as part of its mission by a Federal agency, or else proposed in response to an announcement of agency interest in a particular field. It is alleged that this cost sharing is necessary in order to prove institutional interest in the research. Quite frankly, most of us do not have sufficient resources to support many projects which we believe ought to be carried out.

It is not difficult to understand how such practices can arise in times of tight agency and program budgets. Program and project officers are naturally anxious to stretch their budgets as much as is possible and, therefore, encourage principal investigators to seek contributed funds from the institution wherever possible.

Although the motive of this "informal" cost sharing requirement is easy to understand, the practice is nonetheless injurious to the research enterprise. It must be understood that the funds supplied by universities for this purpose are not new money; they instead have been diverted from the support of other research programs. The total amount of research performed will not be increased; it will only be channeled in particular ways. Any such externally imposed constraint on a university's ability to direct its own research spending leads to a less than optimal use of that institution's resources. Although limited, these resources can be enormously useful to provide insurance so that projects may not lose momentum and staff when extramural awards are delayed. They can also provide needed funds to start new investigators with facilities, equipment and support staff when extramural awards are delayed. They can also provide needed funds to start new investigators with facilities, equipment and support staff until they are able to compete successfully for outside support. In this way, a pool of talent for addressing scientific problems of national interest can be maintained and increased. In such ways the program of the agency may be advanced more than it would be by simply adding the same amount of money on top of an existing grant or contract. It is not just a matter of equity, it is also a matter of efficiency.

There are other ways in which this practice is also undesirable from the standpoint of the agency. Inevitably, the infusion of other funds leads to a dilution of the agency's right to set the goals of the research. More directly, the degree of cost sharing promised by an institution can become a criterion determining which of several competing proposals is funded. On many occasions, institutions may find it appropriate to share in the cost of a project funded primarily by one or another Federal agency. There is no problem when this is the result of the analysis and determination by the institution that this is the best way to use its resources. It is objectionable when this support occurs not because the project has won institutional support based on its own merits, but rather because a need to somehow match Federal expenditures on that individual project. Many institutions have programs for competitive research grants of university funds. A project is not, and should not be ineligible simply because it is receiving Federal support. On the other hand, it should not receive enhanced priority solely because it receives such support. Such forced cost sharing can be very destruc-

tive of the cooperation which is essential between Federal agencies and universities if we are to maximize research productivity.

Statutory cost sharing has become unduly burdensome. A large administrative network has grown up over the 19 years that statutory cost sharing has been in effect. The network is necessary to document rather precisely the apportionment of such costs to research and instruction so as to satisfy Government auditors. This artificial distinction of costs discourages universities from making voluntary contributions.

The second issue which I wish to address is that of the support of graduate students working in areas of interest to the various mission agencies. This committee has already heard testimony regarding some potentially critical problems in the supply of scientists and engineers in the next 10 years. Any shortage in the available pool of technical and scientific personnel will inevitably interfere with the ability of the Nation to carry out critical research in the areas of energy, agriculture, defense and space. I am pleased that the various mission agencies have recognized the importance of supporting the development and training of scientists in these areas. Several agencies have initiated fellowship programs to help assure the Nation of an adequate supply of trained scientists and engineers, in particular critical areas.

A far larger source of graduate student support comes in the form of research assistantships on projects funded by Federal grants and contracts. Graduate training demands research experience. Without exposure to modern techniques, instrumentation and problems, that training is sterile. Correspondingly, research programs need not only the hands, but also the fresh approach and ideas which students can provide. It is reassuring that this relationship seems to be accepted now by the granting agencies. There is to my knowledge little disagreement at this time between universities and Federal agencies regarding the propriety of using grant and contract funds to provide this student support when the students are actually working on the projects. I merely wish to emphasize the importance of continuing this support. It is in the best interests of both the Federal Government and universities, indeed of science and technology as a whole.

One question raised in the statement of purpose for this hearing relates to the effectiveness of different funding mechanisms and instruments. I would like to comment briefly on these mechanisms from my own perspective, although I have drawn heavily for background on the report of the National Commission on Research. Funding mechanisms range from individual research projects, large multi-investigatory research programs, research center, large R&D contracts, which may involve large facilities, and through formula grants to the funding of large national laboratories. Each of these mechanisms plays an important role in the funding of university research, and each may be most appropriate, depending upon the field, nature of facilities needed, and type of problem addressed. The mix of these various mechanisms may differ widely from agency to agency. For example, the Department of Agriculture, unlike the other mission agencies, funds primarily through formula grants.

Nevertheless, each of the mission agencies considered here devotes some fraction of its funds to a competitive, small research project program. The maintenance of such programs seems particularly appropriate since it provides an opportunity for the innovative approaches and thrusts in new directions which frequently comprise the cutting edge of science. In many cases, however, the scale of the experiments or the facilities needed demand the cooperative efforts of a number of scientists and engineers, and large research programs and national facilities and national laboratories required. A prime example of this is the situation in experimental high energy physics. Other examples involve experimental work in fusion, and in many parts of space science. Small seed programs provide the initiative, while large facility grants provide stability continuity and flexibility, which researchers need. This was recognized and formulated as two of the several recommendations of the National Commission on Research. I would not assert that in and of itself a particular funding mechanism is more efficient than another. I do maintain, however, that in certain circumstances a particular mechanisms may be more reasonable, and therefore, more efficient, than another.

The major types of funding instruments are grants, contracts, and cooperative agreements. Cooperative agreements are appropriate when there is a mutuality of goals and control of the research program between the institution and the funding agency. It is not appropriate to use this mechanism to enforce a cost sharing not dictated by the nature of the relationship, as I have discussed previously.

In general, the grant type of funding delegates more authority to the principal investigator and the institution for the management of the project than does a contract. Correspondingly, the agency role is simplified. Universities believe that the grant, an instrument to provide investment in research is well suited for basic research.

The National Commission on Research also recommended assistance as the preferred Government funding mode for research. It is particularly gratifying that the Department of Energy has recently adopted grants as a funding instrument for a number of its programs. Clearly, there will always be research efforts which require the degree of management implicit in a contract. Just as clearly there will continue to be areas of honest disagreement among principal investigators, institutions, and agencies as to whether the degree of control implied by a contract is appropriate.

A reasonable assessment would seem to be that there is increased understanding and concurrence among the parties on this issue. Since the National Commission on Research called upon agencies to be willing to experiment with new concepts as the university-Government relationship evolves, there have been positive responses. This is encouraging.

Thank you.

Mr. VOLKMER. Mr. Dummer.

Mr. DUMMER. Thank you.

Mr. Chairman, members of the task force, my written testimony touches on three aspects of the research grant and contract rela-

tionship between the Federal mission agencies and the universities. I would like now to comment briefly on each of these.

The first is the question of how to preserve in the Federal procurement process the identity of research and development and of the institutions which perform it. This is obviously not a new problem. Almost 40 years ago, Dwight Eisenhower, then General of the Army, in a memorandum in scientific and technological resources, said,

> Within the Army, we must separate responsibility for research and development from the functions of procurement, purchase, storage, and distribution. Our experience during the war and the experience of industry in times of peace indicate the need for such a policy.

Following that memorandum in 1947, leaders from industry, universities, and Government gathered to carry out this policy and made a number of recommendations, two of which are still pertinent today.

First: "Because of the intangible and often unpredictable nature of research and development, the arrangements for research and development contracts must differ from those for procurement of supplies and services."

The second recommendation is the following: "The principles governing the normal operations of organizations capable of performing research and development must be recognized in determining the nature of contractual relationships with such an organization."

It is my belief that the mission agencies which have been the most effective in funding university research have been those which have recognized the differences between the different classes of grantees and contractors and have reflected this in their procurement policies and practices. In some cases, of course, the ability of a mission agency to do this may be either enhanced or inhibited by the manner in which statutory authorities or mandates have been drafted. My written statement cites two examples.

One is the Competition and Contracting Act of 1984 which has just been mentioned. It provides a statutory recognition that the process by which basic research proposals are submitted for scientific and peer review in response to agency announcements of their research interest is in itself a form of competition within the spirit and intent of the act. That act has not been without problems for the universities, but nonetheless, without that particular provision and its prompt implementation by certain of the major mission agencies, I think there could have been a disastrous impact on the orderly funding of basic research, particularly by such agencies as the Office of Naval Research, Air Force Office of Research and Office of Army Research and the Research Office within the Department of Energy.

My second example relates to the regulations proposed in August by the mission agencies with respect to Federal rights and data and copyrights. These regulations fail to differentiate data resulting from university research, from data needed for the competitive procurement or reprocurement of hardware, spare parts and supplies. Subsequently, they could have serious adverse consequences for the university community. They would give Federal agencies broad discretion to control the use and dissemination of technical

data and software by the very universities which had, in fact, generated it.

In addition, the proposed regulations reflect a policy which is incompatible with that adopted by Public Law 96-517. That legislation provided that universities, nonprofit and small businesses, could retain ownership and control over patentable inventions resulting from federally sponsored research in order to commercialize them in the public interest. The effective transfer of technology, however, will not be achieved if patent rights flow to the universities while the right to control the ownership, use and dissemination of technical data in software, which are often intertwined and inseparable from patentable inventions, flows to the Federal agencies. Nonetheless, that would be the case under the proposed regulations, and a number of universities have, in fact, in the last 2 weeks, submitted comments urging that regulations be significantly modified.

I would now like to turn to a second topic, reducing bureaucratic accretion in the administration of research grants and contracts. My point here is that the mission agencies, which have been most effective in funding university research, have also devoted substantial effort to developing simplified grant and contract instruments which recognize the realities of how university research is performed and minimize the phenomena which the National Academy of Sciences Roundtable has characterized as bureaucratic accretion.

My statement cites various aspects of grant and contract administrations which are vulnerable to this phenomenon. It also notes some of the efforts made by mission agencies such as DOE and DID to reverse the process by developing simpler but more effective instruments without sacrificing scientific and project accountability. In addition, some mission agencies are also examining more closely the experience and practice of other agencies, including those of the National Institutes of Health and of the National Science Foundation, which have in recent years taken a number of initiatives in improving research management, some of which are listed in my written statement.

Third and last, I would like to comment on the search for mechanisms by which to balance the requirements of national security against the free flow of scientific communications and, in particular, on the recent evolution of national security controls with respect to university research contracts. Classification is, of course, the best known and the strictest control, but it is so contrary to academic traditions of openness that most universities will not undertake classified research except, perhaps, in separate research centers or separate institutes or in limited circumstances. Nor, presumably, do the Federal agencies wish to classify such research broadly. To quote Assistant Secretary of Defense, Richard Perle, "The price you pay for more classification is to narrow the circle of individuals who have access to information that may be a stimulus to research and development on our part." Consequently, classification does not, as yet, appear to have had a significant impact on university research contracts.

Since 1980, however, export control regulations have received significantly greater attention from the mission agencies and hence, from university contractors. Unlike classified information, techni-

cal data, subject to export regulations, can, of course, be disseminated provided it is not disseminated to foreign nationals or foreign countries without appropriate licensing and within certain requirements.

However, the complexities and the definitional problems of these regulations as they would apply to technical data make them for the most part a rather unsatisfactory method of control with respect to university research activities. In the last few years, therefore, the emphasis appears to have shifted to the definition and control of unclassified but critical technology by the mission agencies themselves. The principal focus at present is probably the Militarily Critical Technologies List maintained by the Department of Defense. The technologies covered by that list, however, are so broad in scope and definition that they appear to cut across large segments of university research.

The Department of Defense activities have been increasingly tempted to place restrictions on the dissemination of information resulting from contracts which appear to involve critical technology or the potential for doing so. A number of groups have, therefore, attempted to develop a workable definition of that segment of critical technology which should be subject to security restrictions in colleges and universities.

The Department of Defense in mid-1984 proposed a draft national policy on the transfer of scientific and technical information. A few months later it announced its own implementation of such a policy. The Department of Defense policy stipulates: one, that classification will be the sole mechanism for control of fundamental research in science and engineering under contracts with colleges and universities; and second, defines fundamental research in terms of the 6.1, 6.2 appropriation categories with limited or rare exceptions. Any restrictions on research not defined as fundamental would, under this policy, be agreed to up front as part of contract negotiations, and universities unable to accept such restrictions could decline the contract at the outset.

I sense some optimism that this DOD formula will, in fact, prove workable provided it is not undermined by conflicting directives within DOD. Its success may also well depend on the extent of which research projects initiated without restrictions are subsequently subjected to controls. If this occurs too frequently or perhaps too abruptly, it will inhibit academic scientists and their research teams from making long-term intellectual commitments to unclassified projects which fall into that grey area of critical technology which may invite controls at a late date.

Mr. Chairman, that concludes my remarks, and thank you.

[The prepared statement of Dr. Abel and Mr. Dummer follows:]

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C. 20515

SCIENCE POLICY TASK FORCE
TESTIMONY ON
SCIENCE IN THE MISSION AGENCIES

ON BEHALF OF

COUNCIL ON GOVERNMENTAL RELATIONS

BY

Marvin E. Ebel
Associate Dean, Graduate School
University of Wisconsin

George H. Dummer
Director, Office of Sponsored Programs
Massachusetts Institute of Technology

October 4, 1985

Mr. Chairman and members of the Task Force on Science Policy, my name is Marvin Ebel and I am Associate Dean of the Graduate School, University of Wisconsin. I have been an active researcher for 30 years, conducting research in high energy physics, supported by the Department of Energy or its predecessor agencies. With me today is George Dummer, Director, Office of Sponsored Programs, Massachusetts Institute of Technology. We are here on behalf of the Council on Governmental Relations, an organization of more than 100 leading research universities. COGR was established to provide information to executive agencies of government with regard to policies, regulations and practices that affect university research. Together, Mr. Dummer and I will give you an idea of procedural matters, some of which assist the conduct of research and ought to be extended or continued government-wide and some practices that hamper the conduct of research and delay technology transfer and should be discontinued.

I will address (1) cost sharing as an externally imposed constraint on a university's ability to direct its own research spending, (2) government support of university research as both an investment in solving problems critical to energy independence, agriculture, defense and space, and as a key ingredient in the development and training of scientists in these areas, and (3) the importance of funding mechanisms and instruments as a means of providing innovative approaches to research.

Mr. Dummer will address how research can be enhanced by, (1) recognizing different classes of grantees and contractors, (2) providing the appropriate climate for research through administrative simplification, and finally, (3) understanding the effect of national security considerations on research at universities.

Mr. Ebel

COST SHARING

The first issue which I wish to take up is that of cost sharing on individual research projects, which may be funded either by grants or

contracts. Let me make clear at the outset that I am not talking about cost sharing which is implicit in a cooperative agreement, nor am I referring to the sharing of the cost of major research instruments or facilities. In these circumstances it may be entirely appropriate for an institution to share in the cost of a joint research program, or the cost of an instrument or facility, especially when the use may involve projects outside the mission of the agency. What I am concerned about is a practice of expecting universities to bear part of the costs of specific research projects. This expectation is rarely [if ever] a matter of official agency or program policy. Nevertheless, it is all too common to find project officials who want to know what fraction of the costs of the project the university, in contrast to the agency contracting for the research, will bear. This in turn leads faculty to believe that they will be required to secure some university funding for each proposal, if that proposal is to be successful. Those of us in research administration at universities are then requested to provide an allocation of the university's resources to a project either already supported (as part of its mission) by a federal agency, or else proposed in response to an announcement of agency interest in a particular field. It is alleged that this cost sharing is necessary in order to prove institutional interest in the research. Quite frankly, most of us do not have sufficient resources to support many projects which we believe ought to be carried out.

It is not difficult to understand how such practices can arise in times of tight agency and program budgets. Program and project officers are naturally anxious to stretch their budgets as much as is possible and, therefore, encourage principal investigators to seek contributed funds from the institution wherever possible.

Although the motive for this "informal" cost sharing requirement is easy to understand, the practice is nonetheless injurious to the research enterprise. It must be understood that the funds supplied by universities for this purpose are not new money; they instead have been diverted from the support of other research programs. The total amount of research performed will not be increased; it will only be channeled

in particular ways. Any such externally imposed constraint on a university's ability to direct its own research spending leads to a less than optimal use of that institution's resources. Although limited, these resources can be enormously useful to provide insurance so that projects may not lose momentum and staff when extramural awards are delayed. They can also provide needed funds to start new investigators with facilities, equipment and support staff until they are able to compete successfully for outside support. In this way a pool of talent for addressing scientific problems of national interest can be maintained and increased. In such ways the program of the agency may be advanced more than it would be by simply adding the same amount of money on top of an existing grant or contract. It is not just a matter of equity - it is also a matter of efficiency.

There are other ways in which this practice is also undesirable from the standpoint of the agency. Inevitably, the infusion of other funds leads to a dilution of the agency's right to set the goals of the research. More directly, the degree of cost sharing promised by an institution can become a criterion determining which of several competing proposals is funded. This may be neither appropriate nor productive of the best research. On many occasions institutions may find it appropriate to share in the costs of a project funded primarily by one or another federal agency. There is no problem when this is the result of an analysis and determination by the institution that this is the best way to use its resources. It is objectionable when this support occurs not because the project has won institutional support based on its own merits, but rather because of a need to somehow match federal expenditures on that individual project. Many institutions have programs for competitive research grants of university funds. A project is not, and should not be ineligible simply because it is receiving federal support. On the other hand, it should not receive enhanced priority solely because it receives such support. Such forced cost sharing can be very destructive of the cooperation which is essential between federal agencies and universities if we are to maximize research productivity.

Statutory cost sharing has become unduly burdensome. A large administrative network has grown up over the nineteen years that statutory cost sharing has been in effect. The network is necessary to document rather precisely the apportionment of such costs to research and instruction so as to satisfy government auditors. This artificial distinction of costs discourages universities from making voluntary contributions.

GRADUATE STUDENT SUPPORT

The second issue which I wish to address is that of the support of graduate students working in areas of interest to the various mission agencies. This committee has already heard testimony regarding some potentially critical problems in the supply of scientists and engineers in the next ten years. Any shortage in the available pool of technical and scientific personnel will inevitably interfere with the ability of the nation to carry out critical research in the areas of energy, agriculture, defense and space. I am pleased that the various mission agencies have recognized the importance of supporting the development and training of scientists in these areas. Several agencies have initiated fellowship programs to help assure the nation of an adequate supply of trained scientists and engineers in particularly critical areas.

A far larger source of graduate student support comes in the form of research assistantships on projects funded by federal grants and contracts. Graduate training demands research experience. Without exposure to modern techniques, instrumentation, and problems, that training is sterile. Correspondingly, research programs need not only the hands, but also the fresh approach and ideas which students can provide. It is reassuring that this relationship seems to be accepted now by the granting agencies. There is to my knowledge little disagreement at this time between universities and federal agencies regarding the propriety of using grant and contract funds to provide this student support when the students are actually working on the projects. I merely wish to emphasize the importance of continuing this support.

It is in the best interests of both the federal government and universities, indeed of science and technology as a whole.

FUNDING MECHANISMS AND INSTRUMENTS

One question raised in the statement of purpose for this hearing relates to the effectiveness of different funding mechanisms and instruments. I would like to comment briefly on these mechanisms from my own perspective, although I have drawn heavily for background on the report of the National Commission on Research. Funding mechanisms range from individual research projects, large multi-investigatory research programs, research centers, large R&D contracts, which may involve large facilities, on through formula grants to the funding of large national laboratories. Each of these mechanisms plays an important role in the funding of university research, and each may be most appropriate, depending upon the field, nature of facilities needed, and type of problem addressed. The mix of these various mechanisms may differ widely from agency to agency. For example, the Department of Agriculture, unlike the other mission agencies, funds primarily through formula grants.

Nevertheless, each of the mission agencies considered here devotes some fraction of its funds to a competitive small research project program. The maintenance of such programs seems particularly appropriate since it provides an opportunity for the innovative approaches and thrusts in new directions which frequently comprise the cutting edge of science. In many cases, however, the scale of the experiments or the facilities needed demand the cooperative efforts of a number of scientists and engineers, and large research programs and national facilities and national laboratories are obviously required. A prime example of this is the situation in experimental high energy physics. Other examples involve experimental work in fusion, and in many parts of space science. Small seed programs provide the "initiative," while large facility grants provide "stability, continuity and flexibility" which researchers need. This was recognized and formulated as two of the several recommendations of the National Commission on Research. I would

not assert that in and of itself a particular funding mechanism is more efficient than another. I do maintain, however, that in certain circumstances a particular mechanism, may be more reasonable, and therefore, more efficient, than another.

The major types of funding instruments are grants, contracts, and cooperative agreements. Cooperative agreements are appropriate when there is a mutuality of goals and control of the research program between the institution and the funding agency. It is not appropriate to use this mechanism to enforce a cost sharing not dictated by the nature of the relationship, as I have discussed previously. In general, the grant type of funding delegates more authority to the principal investigator and the institution for the management of the project than does a contract. Correspondingly, the agency role is simplified. Universities believe that the grant, an instrument to provide investment in research, is well suited for basic research. The National Commission on Research also recommended assistance as the preferred government funding mode for research. It is particularly gratifying that the Department of Energy has recently adopted grants as a funding instrument for a number of its programs. Clearly, there will always be research efforts which require the degree of management implicit in a contract. Just as clearly, there will continue to be areas of honest disagreement among principal investigators, institutions, and agencies as to whether the degree of control implied by a contract is appropriate. A reasonable assessment would seem to be that there is increased understanding and concurrence among the parties on this issue. Since the National Commission on Research called upon agencies to be willing to experiment with new concepts as the university-government relationship evolves, there have been positive responses. This is encouraging. My colleague Mr. George Dummer will describe some of these developments in greater detail.

Mr. Dummer — Because COGR focuses on the administrative and contractual aspects of federally sponsored programs in the nation's colleges and universities, and because I chair its committee dealing with grant and contract policy, my testimony will be directed, first, at some issues

relating to mechanisms and instruments for funding university research, and secondly, at the methods by which restrictions, whether through security classification or export limitations, are placed on university research projects.

UNIVERSITY RESEARCH CAN BE ENHANCED BY APPROPRIATE REGULATION

Federal support of university research is most effective where it recognizes differences between different classes of grantees and contractors. Identical grant conditions for municipal sewer projects and university research may not serve the purposes of either, and procurement contracts intended for commercial vendors supplying hardware and spare parts for defense systems are not the best funding instruments for procuring university research or encouraging innovation by small business.

Failure to recognize these differences is to a degree more pronounced in procurement contracts and since procurement contracts are most often used by the mission agencies, it is there that the problem can be most acute.

In the final analysis, the mission agencies which have been most effective in funding university research have been those which have recognized that the same policies and regulations cannot be applied uniformly to different types of research performers and have adapted their own requirements to the peculiar needs and attributes of different classes of performers - universities, nonprofits, and small businesses among them.

In some cases, the ability of a mission agency to do this may be enhanced or inhibited by the manner in which statutory authorities or mandates have been drafted.

Let me cite several examples.

The Competition in Contracting Act

There is no question in my mind that P.L. 98-369, "The Competition in Contracting Act of 1984," had, early in the drafting process, the potential for some bizarre results when applied to university contracting. Regulations designed to ensure the competitive acquisition and reprocurement of hardware, spare parts and supplies are not easily applied to university research involving unique and innovative proposals which spring from the minds of academic scientists and engineers and their research groups. Scientific and engineering concepts at the state of the art are not as interchangeable as wrenches, ash trays, and toilet seats.

During the drafting process, however, several provisions were added which recognized the different attributes of contractors performing basic research. One in particular, recognized that the process by which basic research proposals are submitted in response to announcements of a Federal agency's research interests, are subjected to rigorous peer or scientific review, and awarded to only a small percentage of those applying, was in itself a form of competition. Without the statutory provision and prompt agency implementation, CICA could have had a disastrous impact on the procurement of basic research by those mission agencies which most significantly support it.

Government Rights in Data Policy

The regulations proposed by the mission agencies with respect to federal rights in data and copyrights are an example of where the failure to differentiate contracts for university research from contracts for the procurement, or reprocurement of hardware, spare parts and supplies, could have serious adverse consequences for the university community.

If the regulations are implemented as proposed they would, in effect:

A. Provide the government with rights in data far in excess of those mandated by law or required to fulfill the government's needs and in a manner which is incompatible with the conduct of research and impossible to implement in a university environment.

B. Constitute a new threat to the unrestricted flow of scientific communications by giving federal contracting officers broad discretion to restrict the use, release and distribution of such data by the university which generates it.

C. Treat the right to copyright research results as a right to be granted at the discretion of the federal agency and not as the prerogative of the authors or the universities.

D. Inhibit the use of third party technical data and computer software on federally funded research by subjecting it to excessive federal rights which compromise the commercial vendor's legal protection.

E. Establish a strong presumption of federal agency control over the transfer of technology not involving patents, a presumption which is incompatible with that adopted for patentable subject matter under P.L. 96-517 and undermines effective transfer of technology by the universities which generate it.

Lets examine more closely the question of technology transfer referred to under E. above.

There has, I think, been a general recognition that this country must devote substantial attention to the manner of achieving technology transfer between the research community and the industrial and commercial sector if it is to remain technologically competitive in world markets. Congress has enacted legislation to achieve this in various areas.

One example is P.L. 96-517, the patent legislation which provided that small businesses and nonprofit organizations, including univer-

sities, could retain ownership of patents on inventions resulting from federally funded research, subject to certain licensing and march-in rights designed to protect the public interest. This legislation reflected a preference for technology transfer by the institution that generated it rather than by the sponsoring federal agency and replaced 26 different preexisting federal agency policies on patent rights. It has, in my view, had a significant impact on facilitating increased interaction between research universities and industrial companies, in many cases improving technology transfer even where no patentable inventions in fact result.

One would assume that any federal policy on rights in data would reinforce the legislative policy adopted for patents. Rights in data, which includes technical data and software, cannot be separated from patent right in many cases. As we move toward an information society, we find that technological advances begin to blur the copyright/patent interface. For example, an integrated circuit may involve a copyrightable pattern-generating software program, a chip design copyright under the new Chip Protection Act, and a patent on the novel functions performed by the integrated circuit, and very possibly a trademark.

Consequently, those involved in technology transfer view patents, copyrights, and other forms of intellectual property as intertwined and believe that rights must flow in the same direction as patent rights.

This is in fact the case for small business contractors under the Small Business Innovation Research Act, P.L. 97-219, inasmuch as they retain ownership in technical data and software in the same manner as they retain ownership in patents under P.L. 96-517.

Under the proposed government data regulations, however, the universities do not retain ownership of technical data and software in the same manner as they retain ownership of patents under P.L. 96-517. Instead universities are subject to the same provisions as commercial vendors of hardware and spare parts.

The solution appears simple. The federal mission agencies could simply apply to universities the same rights in data regulations and contract provisions they now apply to the Small Business Innovation Research Program, therefore, making it possible to transfer technology in a coherent integrated manner.

ADMINISTRATIVE SIMPLIFICATION VS. BUREAUCRATIC ACCRETION

In discussing the appropriate climate for university research, we noted that the mission agencies which have been most effective in funding university research have been those which have adapted their own policies and regulations in a manner which recognizes the separate identities and attributes of different classes of performers, including universities.

Closely related is the manner in which the mission agencies develop grant and contract instruments which recognize the realities of how university research is performed and minimize the phenomena which the Government-University-Industry Roundtable of the National Academy of Sciences has characterized as "bureaucratic accretion." This characterizes the natural tendency of some individual or agencies to address and isolate abuse, or anticipate potential abuse, by drafting new regulations and requirements for inclusion in grants or contracts. This is particularly true in those agencies which tend to confuse accountability with accounting.

There are many aspects of grant and contract administration which are vulnerable to either bureaucratic accretion on the one hand, or to sensible simplification on the other.

For example, fixed start and stop dates compartmentalize research into arbitrary time increments, resulting in time consuming and superfluous administration and accounting adjustments. The procurement model, in particular, assumes that research projects have sharp starting and stopping points. This can be addressed by authorizing universities to allow pre-award costs and to extend completion dates of awards and to

carry-forward underexpended funds or unfunded obligations from one discrete accounting period to another.

Controls imposed by federal agencies with respect to inventory and management of property can be burdensome and unproductive, and can be reduced or eliminated in conjunction with more realistic policies with respect to vesting of title in the institution.

Frequently, the requirements for obtaining approval of various administrative actions, such as budget deviations, travel and the purchase of equipment, services and supplies, create unnecessary delay and effort by involving federal agency personnel, whereas under appropriate criteria these can be delegated to the contractor itself.

Other administrative burdens relate to reporting requirements for scientific progress and results, subcontracting and patent disclosures and filings. Similarly, requirements relating to cost sharing, budget deviations and transfer of costs between projects can generate unnecessary effort.

There are, on the other hand, some agencies, or individual activities within the agencies, which are attempting to reverse the tide of bureaucratic accretion and develop simpler but more effective instruments without sacrificing scientific accountability.

Let me cite several examples of those mission agency activities which are currently taking the lead in attempting to tailor the administration of grant and contract instruments to the needs of research.

DOE - Special Research Grant and Contracts

The Energy Research Advisory Board (ERAB) identified burdensome and inconsistent research procurement procedures in a report to DOE in 1983. The specific recommendations of the Board addressed how to reduce the blurring and diffusion of DOE-university administrative contacts due to the multiplicity of field offices, operations offices, and procurement

offices administering university research contracts; greater use of multi-year awards to ensure stability and continuity in university funding; simplifying and conforming the reporting and administrative requirements on university research projects to the experiences and practices of other federal agencies, and improved communications between senior DOE procurement and program staff and representatives of university research administration in order to exchange views on simplifying DOE's university contract and grant policies and procedures.

The panel noted in its discussion the effectiveness of what it called a unique contract instrument now called the Special Research Contract (SRC), which is a streamlined agreement, in some respects much like a grant. It is characterized as a relatively simple document which calls for minimum reporting, provides for advance funding when needed, and is easily renewed, and in the opinion of some university respondents is even easier to administer than grants for similar projects. DOE has not been able to implement all the recommendations of the ERAB panel; nonetheless, it should be noted that DOE has devoted substantial effort to establishing funding mechanisms and instruments supportive of university participation and in improving communications with university representatives.

Last April, for example, the DOE Office of Energy Research (OER), in order to facilitate the use of grants, established the Special Research Grant. The Special Research Grant was developed with help from and was well received by the university community. It has many of the desirable features of the Special Research Contract in dealing with pre-award costs, budget flexibility, carry-forward of unfunded obligations and unobligated funds.

DOD Short Form Research Contract

With the full cooperation of COGR, the research offices within DOD have developed a Short Form Research Contract which simplifies the process of contracting with universities and other nonprofit organizations for research.

This simplified contract eliminates much of the paperwork usually associated with contracts, and makes negotiating with DOD for a research contract reasonably simple.

Extension of Research Management Initiatives to Mission Agencies

One of the recommendations made by the Energy Research Advisory Board with respect to DOE procurement was to simplify and conform the reporting and administrative requirements on university research projects to the experiences and practices of other federal agencies, including DOD, NASA and NSF.

In this connection, it would appear that DOE and other mission agencies are in fact examining more closely the experience and practice of other agencies including those of the National Institutes of Health and the National Science Foundation, which have in recent years taken a number of initiatives in improving research management.

In May of this year, the Research Roundtable of the National Academy of Sciences listed a number of these in a compilation entitled "Current Agency Initiatives for Improving the Sponsored Research System." They included the following:

NIH - The Javits Neuroscience Investigator Award, a seven-year R01 award given to distinguished investigators with a record of substantial contributions who can be expected to be highly productive for the next seven years.

NIH - The NCI Outstanding Investigator Grant, awarded for a maximum period of seven years but renewable, for the purpose of providing long term support to experienced investigators with outstanding records of research productivity.

NIH - Program Project Grants, awarded to an institution on behalf of a principal investigator for the support of a broadly based, often multi-disciplinary, long term research program with a

particular major objective or theme; and Center Grants, awarded to an institution on behalf of a program director and a group of collaborating investigators, for the support of long term, multidisciplinary programs for research and development.

NIH - The PHS initiative to reduce the administrative burden on grant recipients, including expansion of the authorities delegated to grantees under the Institutional Prior Approval System (IPAS).

ONR - The Total Business System Review (TBSR) which emphasizes review of a university's various business management systems rather than individual contract-by-contract or grant-by-grant transactions.

NSF - Accomplishment-Based Renewal Proposals, which is an alternative mode for submission of renewal proposals under NSF research grants, the intent of which is to decrease paperwork and reduce administrative burdens to the research community.

NSF - Two-Year Extensions for Special Creativity, an experimental mechanism permitting extension beyond the initial grant period in order to offer the most creative scientists increased opportunity to attach adventurous "high risk" research questions in the same general scientific area but not necessarily directly related to those pursued under any existing research grant.

NSF - Fixed Amount Awards, used for certain categories of grants, and intended to help reduce some of the administrative burden and record keeping requirements for both grantees and the awarding agency without a loss in appropriate accountability.

NSF - Presidential Young Investigator Awards, providing cooperative research support for promising young science and engineering faculty.

NSF - Organizational Prior Approval System, which was made available to eligible grantees after a three year experiment conducted jointly with the Association of American Universities (AAU). The experiment dealt with ways to attune the federal grant support system to the needs of grantee management by redefining the grant relationship to (1) delegate most prior approvals to grantees; (2) provide grantees with additional authorities needed to permit effective management; and (3) permit limited aggregating or relating of individual projects.

Universities are now proposing an interagency test, limited in scope and term, to study the effect of delegating a common set of prior approval authorities to universities. The prior approval authorities to be examined have already been delegated to universities by one or more federal agencies, so the test is not to focus on the authorities themselves, but to study the effects and feasibility of extending and standardizing these components of post award management.

University Liaison

Another factor which can have a substantial impact on the effectiveness with which agencies interact with university grantees and contractors is the establishment of offices or activities which have, as a principal responsibility, interaction and liaison with the research community. Such activities include the DOE Energy Research Office of University Affairs and the ONR Office of University Affairs. ONR also has Resident Representatives on site or close to several of the larger research universities. NASA discontinued its office of university affairs several years ago.

IMPACT OF NATIONAL SECURITY CONSIDERATIONS

The implications of national security considerations with respect to the university-government relationship and the broad sweep of scientific communications have become a subject of concern and debate at many levels. For those of us who deal primarily with administrative and legal aspects of university research, the implications of national security are most apparent in the way federal agencies deal with classification and with unclassified but critical information in research contracts.

Classification

The current system of security classification was established in 1982 by Executive Order 12356 and a number of commentators characterized it at the time as reversing the trend of prior security classification systems toward openness, and expressed concern that "academic research not born classified may, under this order, die classified."

Concern has also been expressed that the new order gives greater authority to government officials to intrude upon academic research by imposing classification at any stage of a research project. Thus the Order could inhibit academic researchers from making long term intellectual investments in non-classified projects with features that make them likely subjects for classification at a later date.

I am not aware to date of any significant trend toward the classification of on-going research as a result of the Executive Order. Most universities will not undertake classified research on-campus, except perhaps in separate research centers or institutes, and will disengage from research that becomes classified. For this reason I suspect that federal agencies are as reluctant to award potentially classified research to universities as universities are to accept it.

However, university concerns over the mid-stream classification of on-going research projects appears to have been rekindled by statements

made by government officials with respect to the Strategic Defense Initiative. Faculty members have expressed concern that projects may be classified after it is too late to withdraw without severe disruption to the research, or that, as work becomes increasingly sensitive, it will be turned over to private contractors. Thus, there is again the fear of making long term intellectual commitments to projects that may subsequently be classified.

Export Controls

Until roughly 1980, I suspect that many of us would have thought of classification as the principal method by which the federal government controlled the dissemination of scientific research results for purposes of national security. In 1980, however, a DOD sponsored research program involving Very High Speed Integrated Circuits was made subject to export controls and two universities participating in the program were asked to accept restrictions on the publication of the results and the employment of foreign nationals on the research.

At that point university research administrators, many for the first time, became aware of two sets of export control regulations: the International Traffic in Arms Regulation, or ITAR issued by the Department of State; and the Export Administration Regulation, or EAR issued by the Department of Commerce.

Trying to understand the complexities of the licensing process established by these regulations, and understand what university-generated technical data might be subject to export controls, proved bewildering to many.

As a result, many universities concluded that the imposition of export regulations on university research presented problems no less severe than the imposition of classification, and a number of university presidents publicly urged that where controls were necessary, classification should be used in preference to export controls.

Controls on Militarily Critical Technology

From the standpoint of those actually conducting research and those involved in the administration of university research, the issues requiring attention at the present time relate to restrictions on scientific communications involving critical but unclassified technology, and attempts to arrive at a position acceptable to both the federal agencies and the universities.

The principal focus of this effort is the Militarily Critical Technologies List, or MCTL, maintained by the Department of Defense since 1980.

The technologies covered by the MCTL are so broad in scope and definition that they appear to cut across large segments of university research. Consequently, restrictions on research related to such technologies present problems no less severe than those posed by the export control regulations. A number of universities have again taken the position that such technology should either be classified or publishable without restriction.

A report issued by a Task Force of the Defense Science Board in January 1982 stated the problem as follows:

> "DOD is caught in a dilemma. If it vigorously attempts to regulate the flow of scientific information in the scientific community, it would jeopardize the strength and vitality of the very community it is seeking to revitalize for the sake of national defense. On the other hand, if DOD abandons any attempt at regulation in the university context, it could seriously compromise and, in certain cases, totally undercut other efforts to control the out-flow of militarily critical technology. The middle ground is a difficult one to establish."

In October 1984 DOD adopted a policy which (1) stipulates that classification will be the sole mechanism for control of fundamental research in science and engineering under contracts with colleges and universities, and (2) defines "fundamental research" in terms of the 6.1 and 6.2 appropriation categories with limited exceptions. Any restrictions on research not defined as "fundamental" would be agreed to up front as part of contract negotiations and universities unable to accept such restrictions could decline the contract at the outset.

Mr. SLAUGHTER (acting chairman). Thank you, gentlemen.

In connection with the militarily critical technologies, do you see that we can arrive at a satisfactory working arrangement, or would a great deal of that research have to go into Government laboratories?

Mr. DUMMER. Well, at the present time, the 6.1 and 6.2 categories would cover, for example, most of the research done at my institution on campus.

The 6.3 appropriation, where the controls are likely to be most anticipated, is at my own institution less than a few hundred thousand dollars compared with the millions that come from other sources.

So, the question is how much of the 6.2 category funding would fit within those so-called rare exceptions which have to do with a high likelihood of displaying performance characteristics of military systems or, I think, of manufacturing technology.

At the present time, I would especially hate to speculate how much, but I don't—unless the trend accelerates beyond what I have seen thus far—expect that to be dramatic.

Mr. SLAUGHTER. Yes, Dr. Miller.

Dr. MILLER. Mr. Chairman, I would just point out that in addition to Government laboratories, the not-for-profit institutions such as ours do conduct classified research.

We find it very easy to do. We have special facilities. We worked in some very highly classified areas. We also do proprietary research for businesses. That, in a way, is something that does distinguish us from universities.

I have spent 20 years of my life at Stanford University, so I am very familiar with the university side as vice-president for research and later the professoriate there.

It is very difficult to do classified research or even proprietary research there for very good reasons. But there are other institutions other than the national laboratories where it is done.

Mr. SLAUGHTER. Glad you made that point. Didn't mean to slight the private institutions.

Mr. DUMMER. I might add, Mr. Chairman, of course universities have, under circumstances where it is anticipated and planned and part of their regular program, such as some of the FFRDC's of which the Lincoln Laboratory associated with MIT is one, that performs major classified research.

I think the new software institute, as I recall, Carnegie-Mellon, is going through the process of determining to what extent potential classification may be appropriate there.

I think each institution may decide whether it will or will not be able to respond, whether it is public service or in the interest of national security, whether there is a compelling need by setting up the mechanisms by which to do classified research; but I think they hesitate to do it on the campus proper where the interaction of faculty and students in an open environment is essential.

Mr. SLAUGHTER. Thank you.

Mr. Stallings, do you have any questions?

Mr. STALLINGS. I would like to address a couple of questions to Dr. Levy.

You indicated that over the past couple of decades, the health of university research has become less of a concern and interest to NASA. What do you think accounts for such a change in attitude, and is a reversal of that attitude developing at this time?

Dr. LEVY. What I have said is I have been told by both congressional staffers and people within NASA that the NASA charter mandates the agency to carry out a mission which has as none of its parts the health of university programs, per se.

I would say that within the program offices—and few speak to individuals associated with the agency, particularly those who are charged with running the research programs—they, as individuals, do have some considerable concern over this question.

But the real question comes when moneys are allocated. Is any concern taken over whether or not there will be a large negative or a large positive impact on the university programs? And the answer is no.

I would say that that is a problem, I am afraid, in this part of town as much as it is in the agency when the crunch over real dollars comes in as much as it is in the Office of Management and Budget.

So, I don't think it is a matter of ill will or lack of concern, but in the final event when dollars get sliced off the budget and moved here and there, in all of the parts of this town that are responsible for that process, the university programs do not seem to loom large as major concerns.

Mr. STALLINGS. Also, in your opinion, what is the reason for the failure of the United States to respond to the appearance of the comet, Halley's Comet?

Dr. LEVY. Didn't want to spend the money. There were programs brought forward of a whole various spectrum of opportunities that were brought forward in the later 1970's, and they never made their way up through the agency, through the White House and into the Congress.

I can recall spending an impassioned several minutes on the telephone with the previous Presidential Science Advisor during a budget process, urging that low thrust electric propulsion development continue to be kept in the budget simply to provide the opportunity for the Halley's Comet mission that was being planned, and that simply didn't happen.

I think that it was a manifestation of a turn in national mood and a sense that a loss of national vigor in these areas more than it was anything else.

It is not something that happened in some well-defined office over at the agency. It is something that happened in this town, generally.

Mr. STALLINGS. Thank you.

Mr. SLAUGHTER. Dr. Levy, I think you stated that one of the problems we have in developing young scientists is they don't have very good career opportunities, and so I guess the question—that is equivalent to saying we are not doing enough research in this country generally, scientific research.

Maybe you disagree with that. Maybe I have drawn the wrong conclusion, but if that be true, I would like your comment on that. Is it because the Government is not spending enough? I gather you think so, certainly in the case of space science.

How much of it is attributable to industry not spending enough, and, of course, I know what we have got to do to make Government spend more money is to convince the Congress to set up the right kind of program and so on.

I am glad to have your comments on that, but in particular, if industry is not spending enough, why?

Dr. LEVY. Let me make sort of a general comment. I think that there are several phenomena involved here.

One of the phenomena that is involved is that there has been a market unsteadiness in Government programs, so that there was a time of great vigor 20 years ago in trying to get programs established which expanded university faculties and then followed by a marked turn down which provided bare sufficient research opportunities to keep those who were started 20 years ago working and busy in research programs and providing no opportunities for new scientists following them.

I think part of—there are two issues here. One is that I don't believe that the level of research spending is where it ought to be, and second, the very large swings and fluctuations in the way this Nation supports science have been very damaging in that it filled up all of a sudden all of the positions and career opportunities, and then just as suddenly cut things down by about a factor of two in terms of the real level of expenditure in Federal funds, and then suddenly cut off the opportunity.

So, it is a matter not only of just the level of spending, but it is also this unevenness when we suddenly get excited, and then we lose interest.

I guess I don't feel particularly competent to discuss the question of spending in industry. My major experience and concerns have been with fundamental research programs, and fundamental research is not, in fact, a major component of most of the industrial research activities.

That is a question, I guess I would prefer to defer to somebody else.

Mr. SLAUGHTER. I was going to ask. Other members of the panel may want to comment on this, too.

Dr. Ebel.

Dr. EBEL. Yes. First of all, let me point out, as Dr. Levy just said, you are dealing here in the question of training young scientists with a very long time scale.

You talk about graduate training, which in many scientific areas can approach 7 years past the bachelor's degree. Plus, it has become traditional and necessary frequently to have post-doctoral training of 2, 3, 4 years.

So, you are talking about a time scale of roughly 10 years. One of the problems you have is this problem of fluctuation in that if job opportunities are reduced, then people are discouraged from entering the fields, and so it creates a problem not immediately, but ten years down the road, and this then means that surprisingly, an effect of increased involvement of industries in research can act as

a competition, as an alternative source to the training of basic scientists or to the training of university faculty members.

And so the problem—part of the problem right now which we are seeing in engineering is, of course, job opportunities in engineering are too good.

The problem really is a fluctuation problem here, and my own field 10 years ago, 15 years ago, perhaps, one said that we had enlarged the faculties in the areas of high energy physics so much that there really weren't any more opportunities, and students become discouraged.

Now, we are looking at the fact that median ages are 50, 55 in departments. Ten years down the road, we aren't going to have the faculty available.

So, I think that as Dr. Levy was pointing out, it is not just a question of funding, but it is a question of stability of that funding.

And it is a question also of recognizing that when you are funding, if you want a long-term research program, you have to not only fund the individual research projects, but you have to recognize what the impact of that funding is going to be upon the training of next year's crop or the next decade's crop or next century's crop. That is part of our problem.

Mr. SLAUGHTER. Dr. Miller, do you have any comments on that?

Dr. MILLER. Well, I would really support what has been said, that the steadiness is an important issue.

I suppose sometimes we take the fact that we may have an oversupply of scientists in some areas as evidence that we have been producing too many, but the other side of the coin that you just mentioned is maybe we are not doing enough research that should be occupying them.

In my own testimony, I mentioned I think the process has worked very well by and large, but a more global view of what are important areas to be working in—new areas—is perhaps lacking in our interagency kind of coordination, because we probably are not spending enough in certain areas that are going to be profitable in the future.

Mr. SLAUGHTER. Mr. Dummer, do you have any comment?

Mr. DUMMER. No, Mr. Chairman.

Mr. SLAUGHTER. Well, gentlemen, I want to thank all of you for your testimony today and for your contributions to our task force study.

The task force stands adjourned until October 22 when we will continue this set of hearings on Science in the Mission Agencies and the Government Laboratories.

Thank you all for coming today.

[Whereupon, at 11:50 a.m., the task force adjourned, to reconvene on October 22, 1985, at 9:30 a.m.]

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

TUESDAY, OCTOBER 22, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SCIENCE POLICY TASK FORCE,
Washington, DC.

The task force met, pursuant to notice, at 9:37 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua, chairman of the task force, presiding.

Mr. FUQUA. The task force will be in order.

Today's hearing is the fourth in a series of six hearings on science in the mission agencies and Federal laboratories. This hearing will examine science policy in the Federal laboratories and will also consider the implications of the reemergence of the Department of Defense as a major sponsor of university research.

The first of our distinguished witnesses will be Mr. David Packard, chairman and cofounder of Hewlett-Packard. Among his many activities, Mr. Packard is a member of the White House Science Council where he chaired that Council's laboratory review panel, and he is the Chairman of the President's Commission on Defense Management.

I also might note that in his spare time, he helped design quite a bit of the new Monterey Bay Aquarium which is directed by his daughter and was featured in the June issue of *Smithsonian* magazine. Mrs. Fuqua and I had a chance to visit that back in August, and it is everything that it says about it.

So, Mr. Packard, we would be happy to begin with you this morning.

[A biographical sketch of Mr. Packard follows:]

DAVID PACKARD

Born: September 7, 1912, Pueblo, CO.

Married: Lucile (Salter) Packard April 8, 1938.

Education: Stanford University—B.A. 1934, Stanford University—E.E. 1939.

Honorary Degrees: Doctor of Science, Colorado College, 1964; Doctor of Laws, University of California, 1966; Doctor of Laws, Catholic University, 1970; Doctor of Laws, Pepperdine University, 1972; Doctor of Letters, Southern Colorado State College, 1973; Doctor of Engineering, University of Notre Dame, 1974.

Business: Hewlett-Packard Company, 1501 Page Mill Road, Palo Alto, CA.; Cofounder and Partner, 1939–1947; President, 1947–1964; Chairman of the Board and Chief Executive Officer 1964–1969; U.S. Deputy Secretary of Defense, Washington D.C. January 1969–December 1971; Hewlett-Packard Company, Chairman of the Board, January 1972–.

Director: (Current only) The Boeing Co. 1978–, Genentech, Inc. 1981–.

Trustee: Herbert Hoover Foundation, American Enterprise Institute, The Hoover Institution.

Activities: President, Board of Regents, Uniformed Services University of the Health Sciences 1975–1982; The Trilateral Commission 1973–1981; Fellow, Institute of Electrical and Electronics Engineers; Member, National Academy of Engineering; Lifetime Member, Instrument Society of America; Member, the Business Council (Past Chairman, December 1972–December 1974); Member, the Wilson Council; Member, The Business Roundtable; Member, Industries Advisory Committee, The Advertising Council, Inc.; Member, US–USSR Trade & Economic Council Committee on Science & Technology 1975–1982; Member, Board of Overseers, Hoover Institution, Committee on the Present Danger 1975–1981; Founding Vice-Chairman, The California Roundtable; Director, Alliance to Save Energy; Director, Foundation for the Study of Presidential and Congressional Terms; Vice Chairman, Santa Clara County Manufacturers Group; Vice Chairman, The Atlantic Council 1972–1983; Member, White House Science Council; Director, Wolf Trap Foundation (Vienna, Va.); Co-founder and past chairman, American Electronics Association; Vice Chairman, California Nature Conservancy 1983–; Chairman, U.S.-Japan Advisory Commission 1983–; Director, National Fish and Wildlife Foundation 1985–; Member Commission on Executive, Legislative & Judicial Salaries 1985; Chairman, President's Commission on Defense Management 1985.

Clubs: San Francisco: Bohemian, Commonwealth, Engineers Club, Pacific Union, World Trade; Los Angeles: California Club; Washington, D.C.: Alfalfa Club, Capitol Hill; New York: The Links.

Awards: American Electronics Association Medal of Achievement "For Significant Contributions to the Advancement of Electronics" (1960); Herbert Hoover Medal, the highest honor awarded by the Stanford Alumni Association (June 1966); Peninsula Manufacturers Association "Man of the Year for 1968" (Feb. 1969); Gantt Medal, presented by American Management Association (Feb. 1970); Crozier Gold Medal, presented by American Ordnance Association (and life membership in the Association) (April 1970); "Distinguished Alumnus of the Year", named by Alpha Delta Phi at Stanford University (May 1970); Distinguished Citizen Award, presented by the Palo Alto (Calif.) Chamber of Commerce (Feb. 1972); James Forrestal Memorial Award, presented by the National Security Industrial Association (March 1972); Award for Very Distinguished Public Service, presented by the Federal City Club of Washington, D.C. (March 1973); Business Statesman of the Year Award, presented by the Harvard Business School of New York (April 1972); The Silver Quill Award, from the American Business Press, Inc. (April 1972); Grand Cross of Merit, presented by the Federal Republic of Germany (July 1972); Benjamin Fairless Memorial Medal, presented by the American Iron and Steel Institute (May 1972); Founders Medal (presented jointly to Messrs. Packard and Hewlett), awarded by the Institute of Electrical and Electronics Engineers (March 1973); Business Statesman of the Year, presented by the Harvard Business School Club of Northern California (May 1973); Industrialist of the Year (in conjunction with William R. Hewlett), presented by the California Museum of Science and Industry and its affiliate, the California Museum Foundation (May 1973); Silver Helmet Defense Award, presented by AMVETS (August 1973); Medal of Honor, presented by Electronic Industries Association (March 1974); and The Washington Award, presented by the Western Society of Engineers (Feb. 1975).

Also: The American Society of Mechanical Engineers and the Institute of Electrical and Electronics Engineers (April 1975); SAMA (Scientific Apparatus Makers Assn.) Award, presented jointly to David Packard and William R. Hewlett (May 1975); Gold Medal Award, presented by the National Football Foundation and Hall of Fame (Dec. 1975); Good Scout Award, presented by Stanford Area Council, Boy Scouts of America, Palo Alto (Dec. 1975); Vermilye Medal, presented jointly to William R. Hewlett and David Packard by The Franklin Institute, Philadelphia (May 1976); Award for International Achievement, presented by The World Trade Club of San Francisco (May 1976); Award of Merit, presented by the American Consulting Engineers Council Fellows (Oct. 1977); Achievement in Life Award, presented by the Encyclopedia Britannica (Nov. 1977); Founders Award, National Academy of Engineering (Fall 1979); 1980 Engineering Award of Distinction, presented by San Jose State University (June 1980); Thomas D. White National Defense Award, presented by United States Air Force Academy (May 1981); Distinguished Information Sciences Award, presented by Data Processing Management Association (Oct. 1981); "1981 Citizen of the Year," Police Activities League, San Jose, Ca.; John Fritz Medal, presented by the Founders Society, WESCON (Sept. 1982); Sylvanus Thayer Award, United States Military Academy, West Point, New York (Oct. 1982); and Environmental Leadership Award, Natural Resources Defense Council (May 1983).

STATEMENT OF DAVID PACKARD, CHAIRMAN OF THE BOARD, HEWLETT-PACKARD COMPANY, PALO ALTO, CA

Mr. PACKARD. Thank you very much, Mr. Chairman, and members of the committee. I am pleased to have the opportunity to speak to you on a subject that has been of considerable interest to me over a long period of time.

As I think you know, we had a subcommittee of the White House Science Council that spent about a year looking at the Federal laboratories. We made some recommendations, and I assume that your committee has seen a copy of those recommendations.

In thinking about this, I recall that I first called on the Naval Research Laboratory in 1940, so I have been involved in these laboratories for quite a long period of time. Actually, our company has had a very good relationship with a number of the Federal laboratories because we have been in the scientific instrument business and we have worked very closely with these laboratories over the years.

Now, this morning, I am going to concentrate on a few rather simple but I think rather fundamental recommendations that I believe would result in an improvement in the return we get for the money the Federal Government is spending in supporting research and development, not only in the laboratories but also in the agencies. I am going to begin with some rather simple statements, but I think it is very important to keep in mind what the basic fundamentals of this situation are. I think if we do that, it may be helpful.

I would like to begin by recalling that progress in science comes from two basic endeavors. The first one is people who think, and the second is people who carefully design and conduct experiments. There are two very simple guidelines which, it seems to me, if they are understood and taken into consideration, could make an immense improvement in the way the Federal Government supports science.

First, again, the scientists are people who think. They should be selected and supported on the basis of the quality of their scientific work, not simply on how well they can write a proposal asking for support. When they are supported, they should not be burdened with preparing unnecessary progress reports, effort reporting, and other unnecessary work which simply takes away their time in which they are to do their real work.

The second proposition is that the scientists must have the proper equipment in order to carefully design and conduct experiments. The equipment needed to keep scientific work at the forefront of technology today is much more complex and much more expensive than it was in the past. Modern equipment is more accurate and often includes computational capability which makes it much more efficient, and it is a very serious handicap for a scientist to have inadequate equipment and inadequate facilities for the work to be done. So, it seems to me that when the Federal Government provides financial support for a scientist, the Government should also take into consideration the need for financial support for equipment and the facilities that are necessary to do the work.

I think if this is done, we will all get a better return for the work being supported.

These observations apply to people doing development work as well as basic science. Experimental work for development would include testing to prove the integrity of the proposed design. There would also be drawings and instructions to produce models and so forth. So, these observations, I think, are fairly general and I think if they are kept in mind as various issues are considered by the Congress, they could be quite helpful.

I want to make a few more specific comments about how the agencies might do a better job in selecting the scientists they want to support.

I believe the peer review process is useful, but I don't think it should be carried too far. I have already mentioned that the selection of the people to support should be based on their performance to the fullest extent, and this implies that the peer review process should probably focus more on what the scientist has actually done and not just on what he says he can do.

I have seen many excellent proposals prepared by people who sound very credible but who have had, in fact, a very dismal record in what they could actually do.

In our report on the Federal laboratories, we recommended that each laboratory have a review committee and that the review committee should report not just to the laboratory director but to the agency or organization responsible for the laboratory. The review committee would be, in a sense, another kind of peer review. Quite often what happens is the laboratory committee develops a fairly close rapport with the laboratory director and is not often as objective as it might be in making recommendations. We think that using a review committee to evaluate the performance of a laboratory should serve to reduce the number of routine reports that are now required. In basic terms, an objective review of the work done by the laboratory would be much more useful than the myriad of reports, progress reports, and other things that are now required.

There is another issue here, and that has to do with the fact that good research work cannot always be done in discrete quantums. There should be some continuity, some long-term stability to these programs, and this is done to some extent. Specifically, a Federal laboratory or a college or university that has demonstrated good work should be supported over a longer period of time. I think that this emphasis on longer term support of research activities that have demonstrated good performance would be a very important contribution that would improve the efficiency with which these funds are used.

This, of course, should involve a period review of the performance by a review committee. I think, in many ways, it would be better to reduce the peer review process to the beginning of a new program. I think if you are going to do something, it wouldn't hurt to make a mistake once in a while and have a little more flexibility in who you support. Sometimes, the laboratory director knows about a young scientist in his organization, and his recommendation could be entirely appropriate for a program. These should be reviewed as you go along.

It has often been thought by people who have been involved in the process that the review procedure tends to reduce innovation in that somebody comes up with a new idea completely out of his traditional field and the peer review committee doesn't always understand it, and sometimes you are not able to get things done that could be very productive otherwise.

There is another very specific matter that I think this committee could be helpful with, and it has to do with research at colleges and universities and particularly in that area that is generally known as basic research. Federal agencies and Federal laboratories find it difficult to place research contracts at universities because of the many detailed requirements that are placed on that contracting procedure. I think it would be very helpful if all the Federal agencies and the Federal laboratories could be given specific authority to give contracts to colleges and universities on a sole-source basis. There is, in fact, in my opinion, absolutely no place for competitive bidding for research placed through colleges and universities, and I think this committee could make an immense contribution to American science by obtaining the support of the Congress to exempt research contracts placed with colleges and universities from competitive bidding requirements and also from many of the other requirements such as small business, equal opportunity, and so forth. These requirements take time and add cost and I think, in fact, they don't often help very much with the social reform that is intended.

I suppose, also, it is too much to ask the Congress to refrain from logrolling activities where research at colleges and universities is involved, but it seems to me that here again it would be a contribution if this work could be supported strictly on the basis of its contribution to the quality of American science.

Universities, as I think you know, are having difficulties with the equipment and facilities available for the research people. It varies a great deal, of course, from university to university. Some of the major research universities are getting good support from the private sector, from business, and doing relatively well but, in general, there is a real problem with the equipment and facilities. The Federal Government has done a very fine job in the area of high energy physics where facilities costing hundreds of millions of dollars have been provided, and, of course, this work couldn't be done without this support for these facilities. In my opinion, there are many other areas of science which might make an even more important contribution to our economic well-being, the health of our citizens, and to the quality of life than high energy physics. I think a few tens of millions of dollars for equipment and facilities would bring a big return in the productivity of scientific work in these other areas.

At this point, I want to make a few comments about the tax credit for equipment given to colleges and universities by private sector business organizations. This arrangement, I think, is generally good and I support it, but there are a few problems with it, and I want to point these problems out to you, not with the idea that I am against this tax credit but that there are some additional things that should be considered.

This arrangement does have the advantage that most corporations have an idea about the quality of work being done at various universities, and they tend to give equipment where quality work is being done, where good students are being educated, so this is a very positive feature of the problem. Some corporations, in addition to giving equipment, provide funds for installation, and operation and maintenance. Not all of them do so, and it is very important, I think, that they do so.

Sometimes, equipment is given to colleges and universities, and they don't have the money to install it and keep it in operation. Perhaps this investment credit should be expanded to allow some financial support for installation and maintenance and operation of equipment which is being given to the colleges and universities.

Corporate contributions don't completely solve the problem, however, and I think it is fair to say that some corporations look on this to some extent as an advertising or sales gimmick. I might suggest that probably colleges and universities around the country have received a good many more personal computers than they really need and not enough of other kinds of equipment. So, this is an area—I don't know how to correct it, but this tends to be the situation.

Another problem with this Tax Credit Program is that it does not extend to all colleges and universities on the basis of their real need. I think, therefore, that the Tax Credit Program should be supplemented by direct grants by the Federal agencies, and I think that the Federal agencies and laboratories will receive more for their money if they take the responsibility for making sure that the equipment is available for the people they support.

The Department of Energy has a special problem that I want to mention here. We came upon this in our Federal laboratory study. It is simply that the Department of Energy tends to treat research grants like contracts to do construction rather than contracts to do research. They have field offices that look over the work being done. They often require monthly reports, and I have seen a number of cases where a monthly report by a scientist or an engineer doing research work is just a complete waste of time. I have known a few cases where the person being supported has asked to be relieved of these monthly reports, and the agency has granted that relief. However, this, in fact, requires paperwork by the ton. It is absolutely unnecessary in most cases, and it poses a large burden on the people who are doing research work, and simply takes time from the work they should be doing.

This problem came about, I think, because the Atomic Energy Commission was organized to be able to manage a large number of facility construction programs. Here it was desirable to have field offices and require progress reports and so forth. This apparatus was transferred to the Department of Energy, and it should be phased out. If this could be done, I think it would save many millions of dollars a year and provide a much better environment for the scientists involved to have more time to do the scientific work instead of paperwork.

I want to say a word about Government-owned laboratories like NRL, NBS, and so forth. I am pleased to note, Mr. Chairman, you

have introduced some legislation to help in the administration of these federally operated laboratories and other areas.

I want to emphasize that because these laboratories and other activities are under civil service regulations, they have not been able to hire, motivate, or retain the best scientific people, the scientists, and engineers. They can't get the best young people coming out of the schools and universities, and senior people have a good many attractive offers from outside the Government, so the quality of the personnel is often not what it really should be.

This program could be patterned after one that was in place at the Naval Ordnance Laboratory at China Lake. I visited that laboratory and found that the director was able to do a much better job in keeping, attracting, and motivating his people. This is something I would recommend very strongly that you consider and put into place if you can.

I don't have any real objection to making this program all inclusive. The Defense Department does have some difficulty in attracting and keeping good people, and if it could be done on a broader basis in the Federal laboratories, that would be I think a very good step. But I hope if the full program isn't feasible that you will at least work hard to get this step for the laboratories as a first step in the right direction.

One choice, of course, would be to place the federally owned laboratories that are federally operated under a contractor operation. I don't think it would be wise to do so. I think the present mix between company operated and federally operated laboratories is about right. Some of these laboratories like the National Bureau of Standards, for example, have a long tradition of good contribution to science and technology, and I think it is a good balance to keep some federally operated laboratories. So I would not recommend that these all be transferred over to outside management.

There is another matter that we raised in our Federal laboratory panel, and it is a very important idea in connection with the administration of research work. That is that research people should be allowed to spend at least a part of their time on some ideas of their own choosing. This proposition, I think, is supported by almost everyone who has had much experience in Federal laboratories.

It is simply that if a scientist or engineer is working on a particular project, quite often there are some ideas that occur to him that would be unrelated to that particular project, and sometimes this can be a very important source of innovative ideas. We recommended that at least 5 percent and some members thought it should be 10 percent of a research person's time should be allowed as free time for him to work in areas of his own choosing. I think this is an idea that also should be evaluated from time to time, and it certainly is not going to be productive to allow people to spend 5 or 10 percent of their free time without accomplishing something. We felt that these allowances should be reviewed and those people who in fact come up with some useful ideas over a period of time be given a little more flexibility. So, it should be evaluated on the basis of the results that are actually achieved.

On that point, I want to make a comment about independent research and development for defense programs. I know that your

committee is not involved in the defense-supported activities, but because independent research and development has a possibility of making a larger contribution to areas outside of those related to defense, I wanted to make a comment about this.

The independent research and development for defense programs was originally based on the understanding of the importance of giving scientists and engineers some free time from their assigned work to explore their innovative ideas, the very thing I have been talking about. In about 1970, the Mansfield amendment was enacted by the Congress which required independent research and development to be limited to ideas related to military work. This required that such IR&D as was undertaken had to be justified and documented to demonstrate this work had a military potential.

While this requirement has been repealed, the practice has not improved very much. I think that there are a great many potential commercial fallouts that could be obtained from military research and development if this independent research and development proposition were put back into place on the original basis. I think the areas that your committee is involved in would benefit because, after all, we spend a very large amount of money in research and development in the Defense Department, and I think, to the extent we could get support from the Congress to encourage the Defense Department to change their practices here, it would be very much to the benefit of our country.

These are just a few ideas. There is one other matter I wanted to comment on. I did not include it in my paper.

We are doing at the White House Science Council another study on the relationship of the Federal Government with our universities. This is directed largely to the support of research. We have looked at the two ways in which the Federal Government supports research and development and the way they handle their overhead. One of them is used by the NIH, and the other one is typical of the National Science Council and other agencies.

It seems to us that it is an unnecessary burden to have two completely separate systems in the country here of dealing with this matter of overhead on research programs. I can't give you any strong justification for one system or the other. There are proponents of both, but it seems to me to require universities and other people to deal with two different ways of handling this thing simply adds to the real cost of overhead, and anything we can do to minimize the overhead and put more of the money we are providing into the work of the scientists and the engineers, the research people, I think would have a very productive fallout.

There are many other issues involved here, but I thought I would limit my presentation today to these matters which I think are all fairly straightforward, and I think if these were given some consideration it would in fact improve the return the Federal Government gets for the amount of money it is spending.

I appreciate the opportunity, Mr. Chairman. I would be glad to answer questions.

[The prepared statement of Mr. Packard follows:]

STATEMENT OF

DAVID PACKARD, CHAIRMAN OF THE BOARD

HEWLETT-PACKARD COMPANY, PALO ALTO, CALIFORNIA

BEFORE THE

SCIENCE POLICY TASK FORCE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

OCTOBER 22, 1985

Mr. Chairman and Members of the Committee on Science and Technology, I am very pleased to have this opportunity to appear before you to discuss the subject of science in the mission agencies and the government laboratories. This, as I think you know, is a subject that is of considerable interest to me. I was involved several years ago in a study of the Federal laboratories done by a sub-committee of the White House Science Council. In addition to that, I have had a great deal of experience over the years one way or another with the Federal laboratories. It was about forty-five years ago when our company was first getting started, we had probably twenty or thirty employees at that time, when I called on the Naval Research Laboratory here in Washington. We worked closely with NRL for many years. Since that early beginning our company has been involved many times with government laboratories and I have also had a good deal of involvement, one way or the other, in the mission agencies and including, of course, the Department of Defense.

The Federal government has provided an enormous amount of support for American science during the last four decades. It is in a large part because of this massive Federal support that the United States has taken a leadership role in science over the rest of the world. The leadership of American science has contributed a significant increment of superiority to the armed services of our country. It has enabled us to put a man on the moon and bring him back safely. It has been responsible for brilliant achievements in medical science. American science has made an invaluable contribution to the strength of our economy, our productivity and our competitive advantage in many sectors of the economy.

I am sure your Committee knows all of these things so I will not undertake to document these observations with the facts and figures which I am sure you already have.

Although the Federal support for American science has been very large in magnitude, it has not been as effective as it should have been. I believe there are a number of specific things that could be done to improve the way the Federal government supports American science, in the agencies, in the Federal laboratories and in the colleges and universities of our country. I would like to make some observations on how I believe our Federal science policy should be improved.

Progress in science comes from two basic endeavors, people who think, and people who carefully design and conduct experiments. There are two simple guidelines which, if understood and always taken into consideration, could make an immense improvement in the way the Federal government supports science.

First: The scientists are the "people who think". They should be selected and supported on the basis of the quality of their scientific work, not simply on how well they can write a proposal asking for support. When they are supported, they should not be burdened with preparing unnecessary progress reports, effort reporting and other unnecessary work which takes away the time in which they are to do their real work.

Second: Scientists must have the proper equipment in order to carefully design and conduct experiments. The equipment needed to keep scientific work at the forefront of scientific knowledge is much more

complex and more expensive today than it was in the past. Modern instruments are more accurate and often include computation capability which makes them much more efficient. It is a serious handicap for a scientist to have inadequate equipment and facilities for the work to be done. When the Federal government provides financial support for a scientist, it should also provide financial support for the equipment and facilities needed for that work. If it does so, it will get a better return from the work being supported.

These observations apply to people doing development as well as research. Experimental work for development would include testing to prove the integrity of the proposed design. Also, there would be drawings and instructions to produce models for eventual production. Computer aided design (CAD), computer aided engineering (CAE), and computer aided manufacturing (CAM) provide ways to greatly improve the productivity of development work.

I want to make some more specific recommendations on how the agencies can do a much better job in selecting the scientists they want to support.

I believe the peer review process is useful but it should not be carried too far. I have already said that the selection of the people to support should be based on their performance to the fullest extent possible. This implies that the peer review process should focus more on what the scientist has actually done, not just on what he says he can do.

I have seen many excellent proposals prepared by people who sound very credible but who have, in fact, had a dismal record in what they could actually do.

In our report on the Federal laboratories we recommended that each laboratory have a review committee and that the review committee should report not to the laboratory director but to the agency or organization responsible for the laboratory. It was intended that this review committee work would serve to reduce the number of routine reports required of the laboratory. An objective review of work done by a review committee of peers would be a much better way to evaluate the performance of a laboratory.

After a scientist, either in a Federal laboratory or at a college or university, has demonstrated good work, that program should be supported to provide long time stability for the work; no routine progress reports but a periodic evaluation of performance by the review committee should be made.

It would be very much better to reduce the peer review process at the beginning of a new program. If a mistake is made, it should be corrected in the performance review. Allowing a few mistakes would greatly encourage innovation.

Research at colleges and universities deserves continuing support, particularly what is generally known as basic research. Federal agencies and Federal laboratories find it difficult to place research contracts at universities because of the many detailed requirements placed on the contracting procedures.

All Federal agencies and Federal laboratories should be given specific authority to give contracts to colleges and universities on a sole source basis. There is absolutely no place for competitive bidding

for research placed with colleges and universities. This Committee could make an immense contribution to American science by obtaining support of the Congress to exempt research contracts placed with colleges and universities from competitive bidding requirements and with many other requirements such as small business, equal opportunity. These take time, add cost, and probably don't help much with the social reform that is intended.

I expect it is too much to ask the Congress to refrain from "log rolling" activities where research at colleges and universities is involved. It would be great if this work could be supported strictly on the basis of its contribution to the quality of American science.

Universities are also having a problem with the equipment and facilities available for their research people. The Federal government has done a fine job in the area of high energy physics where facilities costing hundreds of millions of dollars have been provided. There are many areas of science which may make a much more important contribution to our economic well being, the health of our citizens, and the quality of life than high energy physics. A few tens of millions of dollars for equipment and facilities would bring a big return in the productivity of scientific work in these other areas.

I would like to make a few comments about the tax credit for equipment given to colleges and universities by private sector business organizations. This arrangement has the advantage that most corporations give equipment to universities where quality work is being done and this is a positive feature of the program. Some corporations provide funds for installation, operation and maintenance, All should do so.

Corporate contributions are not all to the good, however, for some corporations use this as an advertising or sales gimmick. I would think that colleges and universities have received more personal computers than they really need and not enough of other kinds of equipment.

To give you a feel for the size of these contributions, the Hewlett-Packard Company has budgeted $45 million dollars worth of instrumentation, at list prices, to be given to colleges and universities this year. Our company is not at the top of the list, there are a few companies that do more.

Another problem with this tax credit program is that it does not extend to all colleges and universities on the basis of their real need. The tax credit program should be supplemented by direct grants for equipment by Federal agencies. The Federal agencies will receive more for their money if they take the responsibility for providing equipment where it is needed in the programs they support.

The Department of Energy has a special problem that needs to be corrected. The reason I am telling you about it is because you might be able to help. Our Committee on the Federal laboratories noted this problem and I have discussed it with two Secretaries of the department but the bureaucracy has refused to change.

The DoE treats research grants like contracts to do construction rather than contracts to do research. They have field offices that look over the work being done, they require monthly reports. This requires paper work by the ton. Most of it is useless and this poses a large and unnecessary

burden on the people doing the research work. They do this to the laboratories they support and they also do it to the people in universities doing research.

This problem came about because the Atomic Energy Commission was organized to be able to manage a large number of facilities construction programs. Here it was appropriate to have field offices to keep close control of the program. This apparatus was transferred to the DoE and it should be phased out. To do so would save many millions of dollars a year and provide an environment for the scientists involved to have more time to do scientific work instead of paper work.

I want to say a word about government owned - government operated laboratories like NRL, NBS, etc. Because these laboratories are under civil service regulations they are not able to hire, motivate or retain the best scientific people, scientists and engineers. Our laboratory committee recommended that these Federal laboratories be allowed to establish a better personnel management program. This could be patterned after an experimental program which has been operating at the Naval Ordnance Laboratory at China Lake in California. I visited this laboratory and discussed the program with the director. He has been able to improve the quality of his professional staff because of this program. I hope your Committee will support this program we recommended.

I note that the Department of Defense has proposed a similar program for all of the professional people in the department. I believe that would be a big step forward and I support their program. It may be difficult for the Congress to take the big step at this time but I hope they will at least

support the smaller step we are recommending for the Federal laboratories only.

All federally owned laboratories are not federally operated and one choice would be to put all of the laboratories under private sector management. I do not believe it would be wise to do so. I believe the present mix of federally operated and company operated laboratories is about right, but if the Federal government is going to operate a laboratory, it should be able to do so with a commitment to excellence and under policies that would encourage excellence. That is not the case today.

The Federal Laboratory Panel recommended that research people should be allowed to spend part of their time on ideas of their own choice. This would include areas of science other than that of their main program. We thought at least 5% of free time should be allowed, some Committee members thought it should be 10%. This idea is one that is supported by almost everyone who has had experience administering a scientific project.

This free time is probably the most important source of innovative ideas. Innovative ideas sometimes come from the laboratory director. Innovative ideas that contribute to the quality of American science never come from the Federal bureaucracy. Their "innovative ideas" almost always do the opposite.

The idea of independent research and development (IRD) for defense programs was originally based on an understanding of the importance of giving scientists and engineers some time free from their assigned work to explore their own innovative ideas.

This program was effectively destroyed by the "Mansfield Ammendment" in 1970 when the Congress required IRD to be limited to ideas related to military work. This required that the justification for IRD be documented to demonstrate the independent work had a military potential. While this requirement has been repealed, the practice has not improved very much. This country would receive much better commercial fall out benefit from the vast sums of money spent on military research and development if the original idea for having independent research and development were restored.

I hope some of these ideas will be useful to this Committee in its work to help assure that Federal support for science and technology will be as effective as possible. I know that many other committees of the Congress, probably too many, are involved in this issue. I believe, however, this Committee is in a good position to provide leadership and for that reason, I appreciate the opportunity to give you my recommendations.

I will be pleased to respond to your questions.

DISCUSSION

Mr. FUQUA. Thank you very much, Mr. Packard. It has been a very important and informative review of our Federal laboratories and basic research.

You mentioned toward the latter part of your statement about the time for innovative ideas, 5 to 10 percent of the time. That sounds like a novel idea. Is that a general practice in industrial labs?

Mr. PACKARD. Yes, I think it is. I recall 30 years ago when we were trying to learn how to manage the laboratory of our company that I looked into the ways of Bell Laboratories and General Electric and other companies were doing these things, and this is a common practice.

I think if you look at the source of innovative ideas that a lot of innovative ideas come from work that these people do that is apart from their main mission. I think it is pretty generally accepted that this is a very important, positive element in the administration of any research program.

Mr. FUQUA. When we look at the roles of the Federal labs besides their mission roles that they have and functions, should it be part of their goals to try to undertake programs that create better economic competitiveness, or should that just be left to the private sector?

Mr. PACKARD. Well, I think it is important for all of the Federal laboratories to have a mission that is well defined and that is important. One of the problems we found was that a good many of the laboratories were getting spread too thinly. They were doing things that were not always in their field of expertise. We also felt that these laboratories should make a better contribution to the productivity of our country, of industry, and we recommended, among other things, that closer relationships between industry and the Federal laboratories be developed.

We found that there was quite a variation in the practice here. There were some laboratories that had pretty much an open door to industry. One of the troublesome things we found was that some of the Japanese companies were taking more advantage of work done at the Federal laboratories than some of the United States companies. That was simply that the industry itself had not realized the potential benefits that could be obtained from establishing and maintaining a closer relationship with the Federal laboratories.

I think that matter is being handled better now. Many of the Federal laboratories have open-house programs inviting industry to come in, learn what is going on in the laboratories. They are cooperative programs. Certainly, I think that all of the Federal laboratories have an opportunity and perhaps an obligation, if you want to put it that way, to make contributions on a broader base other than to their specific mission.

The laboratories at Livermore and Los Alamos' primary missions are nuclear weapons, but they have a very broad range of scientific activity. They are doing work on the forefront of computer technology and in other areas where better communication with people in

industry could be a very important element in maintaining the leadership of our country in this whole field of scientific endeavor.

Mr. FUQUA. That brings on another question. What do you see as the role of the Federal laboratories at the present time and into the future? We are trying to look ahead for 30 or 40 years in our study. Where do you see the role of the labs from their present responsibilities to the future?

Mr. PACKARD. Well, it seems to me that you have got back, perhaps, to another fundamental proposition that there are certain things that the Federal laboratories can do which the private sector is not likely to do. Perhaps the private sector could do it, but I think the Federal laboratories do have an important position in the long-term picture.

The National Bureau of Standards is a good example. I think it is a proper Federal responsibility to have a standards laboratory to establish and maintain scientific standards that are provided for the industry. While industry can get together and sometimes does get together in establishing their own standards, it seems to me that this is a responsibility that is very important for the long-term picture. I think that kind of a job should be continued.

There are other areas where the cost of equipment, the cost of a research program is too great for industry to undertake this alone. I think that is another case where Federal laboratories will have a long-term position.

There are cases where the private sector has very little incentive to do things. High energy physics is a good example. There is no way in which you could justify the support of high energy physics which is very expensive as a long-term payout, so I think the Federal laboratories and the Federal Government has a role in that area.

There are other areas of research, for example, materials research. A good deal of research on materials is being done in private laboratories and at universities, but here again there are some areas where, for example, the synchrotron light sources are a useful device to investigate materials phenomena and probably too expensive for industry in general to support.

So, I think the role of the Federal laboratories is a long-term role. I might mention some of the defense laboratories and, again, although that is not in your area of responsibility, I think that over the years the Naval Research Laboratory, the Signal Corps Laboratory at Fort Monmouth, the Naval Ordnance Laboratory have provided in a sense a base of technology and a good coupling with the operational forces that gives a balance to the work that the private sector does.

So, I think there are a number of reasons why the Federal laboratories have been important in the past, and I think these reasons are going to continue to justify their importance in the future.

Mr. FUQUA. You mentioned on page 3 about the peer review process and that it should be based on a person's track record rather than just their ability in grantsmanship. That was my word, not yours, but I think we are talking about the same thing.

How would that impact the new researcher who is coming in who hasn't developed a track record over the years when we need

to provide some means to at least give that person an opportunity to prove himself?

Mr. PACKARD. In the first place, I think the peer review process at the front end still has some utility. I am not saying it should be discontinued. I am simply suggesting we ought to change the emphasis.

There are clearly cases of young scientists who do not have a track record. There they have no alternative but to put a proposal together and somebody knowledgeable should review that proposal and make some estimate about the desirability of supporting it.

I think there are many cases where the laboratory director could recommend that some of his newer and younger research people be supported. Quite often, his judgment would be, I think, just as good as the judgment of a peer review committee.

Also, as I have already mentioned, I think you could be a little bit more open in these programs and maybe not be quite so critical in evaluations and just take a few more chances, give some of the young people who come up with an idea a chance to try it out without having to get a full-fledged peer review committee to approve it. I think in doing that, you might make some mistakes, but in the end, you might come out just as well.

So, what I am suggesting is that we have a little more open process and don't get tied to such official specific routines and regulations. I think a little more openness in the whole thing would result in a better outcome.

Mr. FUQUA. When we were talking earlier about the 5 to 10 percent creative time, should that be included in the overhead costs to, say, universities?

Mr. PACKARD. I think that would simply be included in just a sort of informal allowance. The research support would be for the scientists or engineers' salaries and operating expenses. Those are really direct costs, not necessarily overhead costs.

I think you just give them a little flexibility in saying you don't have to spend all your time on this specific mission and you wouldn't have to have a lot of detailed tracking of that. You would let the laboratory director sort of handle that program, but it would be important that the Congress and particularly the committees which are responsible for this understand that this is being done so that if they heard some fellow got a little too much free time, they could support it.

I don't think you need any increase in the overhead to do this. It would, I suppose, in effect increase your overhead rate a little bit because you would have a little bit smaller direct base on the mission part of the program, but I wouldn't put any stringent rules and regulations on this. I think just indicating to the laboratory director that this is expected of them and let them work out the negotiations on a case-by-case basis.

Mr. FUQUA. One of the inherent conflicts that we are always confronted with—I know I have people talk to me about it—is that sometimes there is the desire on the part of some of the Federal laboratories to conduct basic research that could just as well be done in university laboratories or maybe a private research institution. How do we ensure that the Federal labs are not usurping the rightful prerogatives?

Roland Schmidt, the Chairman of the National Science Board, was sitting where you are a few weeks ago and was talking about the colleges and universities where we train scientists, and then you apply them when they go to work for your company or a Federal lab and some of those, but we must not ever take our eye off the fact that the colleges and universities are where they are trained. To do that, of course, they need a certain amount of basic research and the instructors and professors need that.

Is that—there is probably going to be a continuing conflict, I guess, but I would appreciate your comments on that.

Mr. PACKARD. In the first place, I think it is very desirable for any laboratory of any size to do a certain amount of basic research, because this sort of gives the leavening to the program and gives some interesting things for people to be working on. So, I don't think the Federal laboratories should be prohibited from doing basic research. I think they should do a certain amount of it themselves.

The problem is one I have already indicated that the rules of contracting which are imposed on these Federal laboratories require, in general, that they require competitive bidding for research they place at universities. That is exactly the wrong way to do it.

They can, the laboratory director or their purchasing people, get exemptions from this competitive bidding, but it is a lot of work to do. They have to justify it to somebody, and it is just a whole lot easier, in many cases, to decide we will just do this ourselves.

I think it would be very helpful if this committee and the Congress could make a clear position on this matter that the Federal laboratories should be encouraged to place basic research contracts at universities on a sole source basis.

What you want to do is you want to identify a scientist or an engineer or a group of scientists or engineers who are working on a problem that is of some interest to the laboratory and identify those people who are doing some good work and give them a chance to support their work. To put it out to competitive bidding, and to put all these other requirements on these contracts is the thing that is just too much trouble for these guys to do it, and that ought to be fixed.

Mr. FUQUA. Mr. Ritter.

Mr. RITTER. Thank you, Mr. Chairman.

Mr. Packard, I regret—is this on? It is typical that at a Science and Technology hearing, the microphone doesn't work. No, it is not typical actually.

I regret, Mr. Packard, that I spent the first half hour of your testimony on the rain-soaked road coming in from National Airport in a taxi whose driver refused to pass anybody else. We were at the back of the line, and it was somewhat frustrating.

However, I have followed your work on the Packard Commission quite closely as part of this Science Policy Task Force and also as vice chairman of our Republican House Task Force on High Technology Initiatives.

In previous hearings on the Federal and national laboratories, it was pointed out that while there have been strong missions for a number of these laboratories in the past—very defined missions—

that the current state is a more uncertain one and that there is some seeking of mission to some extent, some drift within certain national and Federal laboratories.

A number of us here are interested in the whole idea of industrial competitiveness. From both sides of the aisle, there was discussion about trying to modify some of the more uncertain missions toward a mission of, broadly speaking, enhancing industrial competitiveness and making the requisite changes within the system in order to fulfill that mission.

Do you have any thoughts on that matter?

Mr. PACKARD. I think this is an important point. I think the Federal laboratories should be encouraged to find some missions that will make a contribution to the overall welfare of our economy and society. It might be competitiveness; it might be other things, too.

One of the difficulties we found was that in all the concern about our energy shortage, there had been a lot of ideas that were being pursued that were not very practical. Some of the laboratories tended to get a very broad range of things they were doing. We felt it would be better for them to develop some expertise in specific areas, and that is really where the idea of missions came about.

In looking at the question of what the laboratories might do to help with our competitiveness, there were several things that came up. Specifically, if you look at almost any area of science and technology, we are limited in what we can do by our knowledge of materials. This is true in electronics, it is true in aviation, it is true in the automobile industry, it is true in almost anything else.

One area that we thought should be emphasized would be to have the Federal laboratories have a stronger role in the field of materials. This is the kind of area that I think should be encouraged.

As you know, there is a great deal of interest in supercomputers. Supercomputers have limited utility in the overall competitiveness of our economy. They have been utilized for rather special things such as weapons design and a few other areas. With the trend in computer technology, with the capability of the performance going up and the costs coming down, it is very likely that supercomputers will have a much larger, much broader role in industry in doing some things that simply weren't done before.

Here, the Federal laboratories, Livermore Laboratory, for example, and some others are doing some work in this area, and they are making it available to business and industry with some communication both ways. So, I think there are already some things that are being done that will enable the Federal laboratories to make a more important contribution in areas that will help our long-term competitiveness of our economy.

Those are just a couple of examples, but I think this is something that should be encouraged.

Mr. RITTER. Do you envision any need for adapting the steering mechanisms of some of the Federal and national laboratories so that there is somewhat of a privatization of the research directions, or do you feel that this will settle out by itself?

Mr. PACKARD. What we essentially recommended was that these laboratories should have a review committee of professional people, scientists, and engineers, and probably some business people, too,

that would monitor the progress of the laboratory, make recommendations as to what fields they should enter, and generally supervise them and monitor them on the basis that they should develop programs of excellence in whatever they do.

I think that kind of an approach, by allowing people from the private sector to participate in these laboratory committees, would probably in the long term result in a better choice of program than, for example, trying to have the Congress sit down and decide what ought to be done or to put some arbitrary rules on it.

I think that the extent to which you can encourage the laboratories to concentrate on the mission—concentrate on building excellence in whatever they are doing—and open communication with the private sector, and particularly with a review committee that would evaluate performance and report to the mission agency or whoever is managing the program, that this sort of a little bit more flexible arrangement would be much better than trying to sit down and decide this laboratory should do this and this will do that and so forth.

There are certain exceptions, of course. In the defense laboratories, they have to work on nuclear weapons and there are specific areas in defense where you maybe want to have a laboratory targeted for a defense objective, but I think for the laboratories this committee is working with, it would be very desirable to have an emphasis on encouraging them to make a contribution to the productivity and the quality and so forth of our economy.

I think to do it on a broad basis with getting expertise in to spend some attention, pay some attention to each individual laboratory is the way to go. And I think that is already being done to some extent. I think there is a good start being made, and I would simply encourage what is already being done.

Mr. RITTER. There is a general consensus that energy is not the crucial mission that it once was. At one point, we had AEC laboratories. At the next stage, we turned them into Energy Department laboratories in order to solve the energy crisis or to approach the energy crisis. But I think it is fairly well accepted that these days we don't have an energy crisis, yet we have a need to justify a variety, a whole wide range of programs, on an energy basis. Eventually, that has to be the justification.

Do you sense that some moderation of the direction of the mission within the Energy Department or to somehow find some other umbrella might help in targeting the resources a little more closely toward the needs?

Mr. PACKARD. If I understand your question, I think there are essentially two sides to this problem. There are certain laboratories that, for valid reasons, are going to have a fairly specific mission. I think it would be desirable for those laboratories to become involved in a certain amount of activity that is related to their mission but not strictly on it.

In other words—well, you have this going on already that the Lawrence Livermore Laboratory is doing some work that is not defense in areas where they have developed a great deal of expertise because of the defense activity. That is true, I think, of Los Alamos to some extent. You are going to hear a little bit more about that, I guess, this morning.

The other side of the coin is that there are a number of laboratories which originally had missions. Argonne is a good example. They were in on the very development of nuclear energy and had an important role. They were sort of overtaken by developments otherwise, and they ended up without a very strong position in their original field.

It seemed to us that it would be desirable to encourage all of the laboratories to develop some special expertise which we call their mission and thereby try to develop a program of excellence. This, we felt, would be much better than the alternative which would seem to be the case when a laboratory is simply going on trying to find enough work to keep it busy. There was a lot of that going on. The director had a certain level of people, and he felt an obligation to keep them going, so he would go around and find any old job he could do, in effect, to keep the program together.

That seemed to us to be not the most effective way to utilize these resources, so this idea of a mission really came about from the fact we thought the laboratories should be committed to developing a field of excellence that they had a little special expertise in and then the way this expertise would be utilized would depend on what the field happened to be.

Mr. RITTER. But if that field is overall energy, doesn't that somewhat limit the innovative aspects in approaching new missions to the tail of the dog or the periphery of the field?

Mr. PACKARD. Sure, it does if you make the requirement for a mission too tight. I think——

Mr. RITTER. In other words, I guess my question is, is the Energy Department set up to accommodate the shift from what used to be AEC and then an energy crisis to a kind of crying need to have some U.S.-style MITI's in our midst?

Mr. PACKARD. I think they should have some flexibility and it could be and probably will be that over the years the mission could change, that they find they are getting involved in some new idea.

One of the important things, I think, is you find a line being too concentrated and too dispersed. You need some concentration in order to build up a position of excellence. You need a little flexibility in order to look at ways in which this excellence could be applied in innovative ways. So, you need some flexibility.

I guess the best answer is that it ought to be not one way or the other; you ought to steer a course somewhere in between.

Mr. RITTER. Mr. Chairman, I have one other brief question, but I would like to yield back to you because I have taken some fair time here.

Mr. FUQUA. Go ahead. We still have three more witnesses, however.

Mr. RITTER. OK. The last question and briefly, are you satisfied with the Federal response to date of the recommendations of the White House Science Council study which you chaired on Federal laboratories?

Mr. PACKARD. The answer is no. I think you know the history of most of these commissions. They make their recommendations and, quite often, they are filed away and no one pays any attention to them.

I am encouraged by the fact that there has been some positive response. There have been established some supervisory committees along the lines we have recommended. There have been, in some of the laboratories, an increase in the amount of free time they are allowing their research people. I think, in general, there has been some encouraging response.

We had a review of this about a year or so after the Commission report was made, and I was encouraged that people had paid some attention to the report and had done something about it.

I am disappointed in the response we have had on this recommendation to get the wage and salary administration out from under the Civil Service regulations. That was a matter where I thought we had the support of all the key agencies, the Department of Defense and NASA and the other people who all thought this was a great idea. It got into the bureaucracy and took about a year and a half and got completely turned around. So, I wasn't satisfied with that. I am delighted that your committee is taking a positive position on this, because I think that is an important contribution.

So, the answer is I am not satisfied, but I think we did have some fairly good response to the recommendations that we made.

Mr. RITTER. Thank you, Mr. Packard.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Ritter, and thank you very much, Mr. Packard. We appreciate your taking your time to be here with us. You certainly come from a background that can be very helpful to us, and we thank you very much.

Mr. PACKARD. Thank you for the opportunity.

[Answer to questions asked of Mr. Packard follow:]

DON FUQUA, Florida, CHAIRMAN

ROBERT A. ROE, New Jersey
GEORGE E. BROWN, JR., California
JAMES H. SCHEUER, New York
MARILYN LLOYD, Tennessee
TIMOTHY E. WIRTH, Colorado
DOUG WALGREN, Pennsylvania
DAN GLICKMAN, Kansas
ROBERT A. YOUNG, Missouri
HAROLD L. VOLKMER, Missouri
BILL NELSON, Florida
STAN LUNDINE, New York
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
NORMAN Y. MINETA, California
MICHAEL A. ANDREWS, Texas
TIM VALENTINE, North Carolina
HARRY M. REID, Nevada
ROBERT G. TORRICELLI, New Jersey
FREDERICK C. BOUCHER, Virginia
TERRY BRUCE, Illinois
RICHARD H. STALLINGS, Idaho
BART GORDON, Tennessee
JAMES A. TRAFICANT, JR., Ohio

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-6371

MANUEL LUJAN, JR., New Mexico
ROBERT S. WALKER, Pennsylvania
F. JAMES SENSENBRENNER, JR., Wisconsin
CLAUDINE SCHNEIDER, Rhode Island
SHERWOOD L. BOEHLERT, New York
TOM LEWIS, Florida
DON RITTER, Pennsylvania
SID W. MORRISON, Washington
RON PACKARD, California
JAN MEYERS, Kansas
ROBERT C. SMITH, New Hampshire
PAUL B. HENRY, Michigan
HARRIS W. FAWELL, Illinois
WILLIAM W. COBEY, JR., North Carolina
JOE BARTON, Texas
D. FRENCH SLAUGHTER, JR., Virginia
DAVID S. MONSON, Utah

HAROLD P. HANSON
Executive Director
ROBERT C. KETCHAM
General Counsel
JOYCE GROSS FRENWALD
Republican Staff Director

October 24, 1985

David Packard, Chairman of the Board
Hewlett-Packard Company
1501 Page Mill Road
Palo Alto, CA 94304

Dear Mr. Packard:

Thank you for your excellent testimony before the Science Policy Task Force on October 22, 1985. Enclosed are a number of questions that Members of the Task Force would like you to answer, in order to supplement the record of the hearing.

We would appreciate your responses to these questions by November 15, 1985. If you have any questions regarding this request, please contact Dr. Harlan Watson of the Task Force Staff at 202/225-4320.

Sincerely,

DON FUQUA
Chairman

DF:W
Enclosure

Thank you very much

QUESTIONS FOR THE RECORD

HEARING ON "Science in the Mission Agencies and Federal Laboratories"

TASK FORCE ON SCIENCE POLICY

October 22, 1985

Mr. David Packard

1. Do you anticipate that without a personnel management program similar to the experimental one at the Naval Weapons Center that Federal laboratories will have a shortage of quality technical staff?

2. Facilities and equipment for science are expensive. How can Federal agencies with decreasing or stable research budgets fund facilities and equipment at universities and Federal laboratories without taking funds from researchers? How do industrial research organizations handle the tradeoffs among facilities, equipment and researchers?

3. What should be the policy toward establishing new Federal laboratories and reorienting existing facilities?

4. Among the government-owned, government-operated laboratories, what criteria would you apply in deciding which laboratories should remain under civil service regulations and which laboratories should "be allowed to establish a better personnel management program"?

5. It is claimed that basic research in industry is nearly non-existent. How dependent is industry on the Federal Government for basic research? What would motivate industry to increase its basic research activity? Is the perceived compartmentalization of research by government and academia and development by industry necessarily bad?

RECEIVED
NOV 25 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

HEWLETT-PACKARD COMPANY
1501 PAGE MILL ROAD
PALO ALTO, CALIFORNIA 94304

DAVID PACKARD
CHAIRMAN OF THE BOARD

November 21, 1985

The Honorable Don Fuqua
Chairman
Committee on Science and Technology
Rayburn House Office Building, Suite 2321
Washington, D.C. 20515

Dear Chairman Fuqua:

I am pleased to answer the questions you raised in your letter of October 24th. I apologize for the delay in responding but I am arranging to send this letter by special messenger with the hope that you receive it in time for further deliberations of the committee.

1) I believe that without a personnel management program similar to the experimental one at the Naval Weapons Center that Federal laboratories will have an increasingly severe shortage of quality technical staff. The quality of staff who run all these laboratories is already beginning to deteriorate and the situation will certainly become worse unless this constructive action is taken.

2) I believe the objective of Federal support for research should be made as effective as possible and this can not be done without providing some funds for facilities and equipment in addition to personnel costs. I am quite sure that if some of the other recommendations I made were followed, particularly those relating to the elimination of unnecessary paper work, that more funds would be available which could be applied to facilities and equipment for the work being supported. In a good many cases research people are able to get funds from industry and other sources, but in doing this it always takes time away from the important research work. One idea which might be helpful would be for the Federal government to provide funds on a matching basis. This would help because it is doubtful the Federal government would be able to meet the entire needs of facilities and equipment and a matching program would help.

I have taken the liberty of asking a friend of mine, Franklin M. Orr, Jr., who is doing important research work at Stanford University funded by the Department of Energy, to respond to this question and a copy of his letter is attached for your information.

Industrial research organizations always consider the need for facilities and equipment in authorizing research programs. Our company, for example, would not think of authorizing a research program in our own laboratories without making sure the facilities and equipment necessary are available. This, of course, means that the total cost of research is more than the cost of personnel, and I am quite sure the Federal government would get a better return from the dollars they spend on research if the facilities and equipment problem was considered as an important part of obtaining good research.

3) I believe new Federal laboratories should be established in the future only when there is a new important mission identified that is not being effectively handled by existing laboratories. This is a basic approach already used in high energy physics, astronomy and a few other areas, but I think there are not likely to be many requirements for new Federal laboratories. I think it would be very desirable to consider the possibility of reorienting existing laboratories when new missions are identified, particularly to the extent the talent and facilities of existing laboratories could be adapted to the new mission.

4) Although our Federal laboratory study committee did not visit all of the government run, government operated laboratories it was our impression that they all would benefit by being allowed to establish a better personnel management program. The basic criteria should be whether or not they are able to attract, motivate and keep a high quality professional staff. Many Federal laboratories have a certain prestige which helps them to attract and keep a good professional staff, but the salary differentials between government operated laboratories, other laboratories and industry, have simply become too large to assure that government operated laboratories will have highly trained and highly motivated staffs in the future.

5) Basic research in industry is being done extensively in some industries, although the universities and the government do a much larger share.

In the electronic industry the research laboratories of the General Electric Company and the Bell Telephone Laboratories did a great deal of basic research in the early days before World War II. Other large organizations such as IBM also support basic research. Du Pont and other companies in

in the chemical industry have had strong programs in basic research over the years, but at the same time it is true that some industries do very little basic research. I think the tax credit for research and development is a positive factor in encouraging industry to support more basic research even though the larger part of industry research is directed toward specific new product development. I do not believe the compartmentalization of research by government and academia and development by industry is necessarily bad. I believe what is needed is more communication among the organizations doing research, and I believe communication among the participating parties has increased substantially over the last few years. The Federal laboratories have a number of programs which enable industry to learn what the laboratories are doing and to obtain help from the laboratories in their own research programs. Industry is supporting a great deal of research at the universities all across the country, and in doing so they are increasing the communication between universities and industry.

The only basic recommendation I could make would be to modify the tax credit for research to allow it to extend to basic research supported by industry at universities and other independent research organizations.

I appreciate the opportunity to express my views on the important work your committee is doing.

Sincerely,

David Packard

DP/lgk
Enclosure

STANFORD UNIVERSITY

DEPARTMENT OF PETROLEUM ENGINEERING
School of Earth Sciences

MITCHELL BUILDING 360
STANFORD, CALIFORNIA 94305-2170
(415) 497-4744

November 12, 1985

11/14

Mr. David Packard
Chairman of the Board
Hewlett-Packard Company
1501 Page Mill Road
Palo Alto, CA 94304

Dear Dave:

I have the following observations on the questions raised by the House Committee on Science and Technology:

Question 2. Facilities and equipment.

There is no question that facilities and equipment are expensive. One of the central problems facing an academic scientist and his department chairman and dean is to find the resources to provide laboratory space and the equipment to allow the researcher to work at the forefront of the field. In some areas, it now takes more money to equip a high quality lab than it does to endow the faculty position the equipment is meant to support. There is no simple solution to the problem. No doubt university faculty and administrators will continue to struggle with it for a long time.

There could be improvements, however, in the way funding of research is handled. As you know most of my experience with Federal funding is with the Department of Energy. A recent request for proposals, to which I responded, contained the statement that the research organization "is expected to furnish all property (including but not limited to facilities, equipment, special tooling and material) necessary for the performance of the work defined in this solicitation." I responded even though the equipment I need is not available now, in effect committing to find other sources for the funding required. The funding was awarded, and hence, I have spent much of the last month trying to raise funds from oil industry. Thus, instead of working on our research I am spending significant portions of scarce research time on additional fund raising. To me it seems that recognition by DOE that research costs are a mix of equipment and personal costs would be much more sensible. To be sure, in an environment in which total funding is fixed funding of some equipment and facilities would reduce funds available for other costs. It would be better, I think, to fund some work adequately, including equipment needed, rather than supporting only noncapital costs for projects without adequate equipment. If funds are limited, as they always are, then it would be better to fund the true cost of the research than to ignore the equipment side. Industrial laboratories, for example, have no choice but to provide funding for the full cost of research they undertake.

Question 5: Basic Research.

This question is hard to answer because it is hard to define basic research. If basic research is only that which has no practical application, then it is probably true that basic research in industry is limited. That definition seems too restrictive to me, though. There are many industrial research organizations that investigate underlying physical principles because they need to understand the physical behavior to design products and control processes. The oil and electronics industries offer many examples of high quality research in support of commercial objectives. The Federal government, particularly NASA and the Department of Defense, has also had a significant role in supporting relatively fundamental research performed in industrial settings.

It seems clear that there is definitely a need for some support for really long-term research, for which immediate applications are not yet apparent, because none of us are very good at foreseeing what will and will not be useful eventually. That work probably ought to be done mostly in universities, and the support should probably come mainly from the National Science Foundation and other Federal sources.

There is also a need for applied work in universities. Many graduate students will eventually work in industrial research organizations, and they and the organizations benefit from graduate research on problems with some connection to practical applications, however tenuous.

It seems to me what is needed is a reasonable overlap between the work going on in industry research organizations and academic laboratories. With adequate communication, each will stimulate the other. It makes sense that university research lean toward longer term research and underlying, unifying principles, with specific applications being pursued more heavily in industry. Industries with vigorous research programs are, of course, best equipped to take advantage of work done in universities and to have some impact on the problems attacked by university researchers. Thus, I do not think that strict compartmentalization is desirable. I am not sure how industry can be persuaded to increase its research activity except to argue that in many industries, competitiveness in the long term is strongly influenced by the quality of their research effort.

I hope some of this rambling is useful. I think the country would have a more productive national research if the recommendations you made recently were adopted. Those of us in the trenches thank you for trying.

Sincerely,

Lynn

Franklin M. Orr, Jr.
Associate Professor

/aeo

Mr. FUQUA. Our next two witnesses will be Dr. Eugene Stark, Industrial Initiatives Officer at Los Alamos National Laboratory and Chairman of the Federal Laboratory Consortium which is made up of over 325 Federal R&D labs and centers; and following Dr. Stark will be Dr. Will Hess, Director of the National Center for Atmospheric Research. Dr. Hess has broad experience in the Federal Establishment and served as both a research scientist and administrator with the Atomic Energy Commission, NASA, and NOAA.

Dr. Stark, we will begin with you. When you have completed, we will hear from Dr. Hess, and then we will have some questions.

[A biographical sketch of Dr. Stark follows:]

DR. EUGENE E. STARK, JR.

Chairman, Federal Laboratory Consortium for Technology Transfer.

Professional position: Industrial Initiatives Officer, Los Alamos National Laboratory, Los Alamos, NM 87545, Tel. (505) 667-4960.

Dr. Stark was born and raised in Miami, Florida. He was educated at MIT in the Department of Electrical Engineering, receiving B.S. and M.S. Degrees in 1969 and ScD in 1972. He held an NSF Graduate Fellowship, 1968-1971, and a Hertz Foundation Fellowship, 1971-1972. He participated in a co-op program at IBM, with two summer assignments at the System Development Division and one six month assignment to the Thomas J. Watson Research Laboratory.

He joined the Los Alamos National Laboratory in 1972 in the Laser Fusion Program. He participated in experimental and theoretical laser research and development and held Deputy Group Leader and Project Leader positions in that program.

During a two year assignment to the Director's Office staff, 1974-1976, he developed a technology transfer program for Los Alamos and has headed this effort ever since. When Los Alamos joined the Federal Laboratory Consortium in 1975, he became the Laboratory's representative; he became Mid-Continent Regional Coordinator in 1977, and was elected Chairman in 1980.

His present responsibilities at Los Alamos include technology transfer; the development of institutional goals, and implementation of strategy for cooperation with industry; and fulfilling the functions of the Office of Research and Technology Applications mandated in the Stevenson-Wydler Technology Innovation Act. He received a Distinguished Performance Award from the Laboratory in May, 1985.

He is a member of the Boards of Directors of the Los Alamos Economic Development Corporation, the New Mexico Technological Innovation Program and the New Mexico Industries Development Corporation.

STATEMENT OF DR. EUGENE E. STARK, JR., INDUSTRIAL INITIATIVES OFFICER, LOS ALAMOS NATIONAL LABORATORY, LOS ALAMOS, NEW MEXICO; AND CHAIRMAN, FEDERAL LABORATORY CONSORTIUM

Dr. STARK. Thank you very much, Mr. Chairman.

I am pleased to have this opportunity to discuss some issues related to the future of science as requested by this committee, in particular, in the areas of the roles and missions of the Federal laboratories, R&D coordination, and also the role of applications in strengthening science.

I would like to begin with what I think is an important underlying perspective, and that has to do with the key role of the technical leader of a Federal laboratory, whether his title be director, technical director, or chief scientist. I think we would all agree that that job is a very challenging one, but perhaps the greatest responsibility of that leader of a laboratory is in maintaining the morale and productivity of an excellent technical staff. It is all the more important because that responsibility and performance is one

that is very difficult to measure, and I believe that responsibility makes some of the more quantifiable measures of a laboratory director's success pale in comparison.

My point then is that given a general role of Federal laboratories, a mission for that particular laboratory and program assignments, the agencies or operators with cognizance over that laboratory should support, not manage, those technical leaders. They already have and cannot really share with those outside the laboratory the very important ability to, as I said, influence the productivity and morale of their staff.

Turning now to the role of Federal laboratories, I think fairly generally it is to attract, retain, and support the best scientists and engineers who choose to work for Federal laboratories in basic and applied research, development, engineering, and testing as desired by the Government.

There are several specific attributes that make the Federal laboratories from other research performers. First of all, many of them span the spectrum from basic and applied research all the way to development and engineering and, in some cases, applications. It is very important because many of the specialty applications or programs assigned to Federal laboratories are much more applied science than they are engineering or development. For that reason, these applied scientists need a direct infusion of information and ideas from basic research. Furthermore, those engaged in applied science need to maintain currency, renewal, and the intellectual stimulation that comes from close cooperation with those performing basic research.

Second, I believe the Federal laboratories are important institutional complements to universities and industry. They are institutions where basic and applied research can be undertaken without heavy teaching loads or any teaching load. On the other side of the coin, they are able to undertake applied research and engineering on much longer range and riskier programs than may be available to industry.

The laboratories, therefore, provide, if you will, a third sort of choice for careers for scientists and engineers, allowing individuals to fit themselves best to the institutional opportunities. Furthermore, this additional opportunity for employment strengthens the whole technical community.

Another role of Federal laboratories is that multidisciplinary and team approaches to research can be much more easily done there in many cases, because of the breadth of their organizations, the fact that there may be less disciplinary barriers, and there is quite a bit of staff flexibility that may permit staff that began as a physicist or a chemist to do engineering or vice versa during his career.

Another role is that the laboratories can maintain long-term Government programs with the assignment of top quality staff specifically because those long-term programs can be the prime mission of their organization.

Finally, some other roles include the maintenance of major experimental facilities, maintaining major technology bases for the Government, and also the fact that at least their unclassified results are fully publishable. There is no proprietary information within the Federal laboratory system.

Turning now very briefly to the mission issue within Federal laboratories, I think it is fair to say that several of our Federal laboratories are the largest R&D institutions ever to exist in this world and, to some extent, we are therefore learning by doing. But any such institution has to have a unifying primary mission that permeates the entire organization and creates a strong institutional culture. This mission should be reviewed on a regular basis and, if there are changes contemplated to a laboratory's mission, they should be changed carefully but also changed rapidly in order to avoid what some will call mission malaise but, in particular, to maintain the most excellent technical staff and particularly the motivation of that staff.

Many laboratories, of course, have secondary missions that may involve areas such as education or technology applications. These secondary applications should be led or spark-plugged, if you will, by individuals carrying a careful balance between those secondary missions and the primary mission and, wherever possible, contributing strongly to the primary mission of the laboratory.

I was asked to address the possible contribution of our Federal Laboratory Consortium to R&D coordination among the Government labs and between the Government labs and outside research performers. Very briefly, since some may not be familiar with the Federal Laboratory Consortium, I will describe it.

We have as members of this Consortium about 350 Federal laboratories from 11 agencies. We are responsible for about 85 percent of the Federal Government's in-house expenditure of R&D dollars. We network together in basically an interpersonal network to make for better accessibility of Federal technology to outside users. This work includes development and replication of methods of outside cooperation, training of individuals, recognition and promoting awareness of the value and availability of Federal technology on the outside.

Returning to the primary issue, this is a very important one because it strikes to the best use of technical resources in this nation, not just governmental, but all science and technology resources. I would suggest as an umbrella for this discussion collaboration to mutual benefit, both on a personal and institutional basis.

Collaboration provides much stronger support to both Government and nongovernmental efforts, renewal of individuals, and sharing of ideas. It is very important in the science and technical communities.

First of all, a bit of a perspective. Between the Government and the outside, any such collaboration needs to be initiated by the outside. It is not terribly credible for the Government or Government laboratories to be marketing their resources blindly to the outside. However, the laboratories need two things. They need pragmatic accessibility to their technology by the outside, and, even more importantly, the outside organizations need to have an awareness of the value of Federal technology, Federal science, and of that accessibility.

Within the Government itself, R&D coordination is really the responsibility of the laboratory director. In both cases, however, what may be needed is a strong network of support, communication, and cooperation with a very active can-do attitude.

Now, my answer to the original question as to whether the Federal Laboratory Consortium might contribute to this is yes, indeed, and we are doing some of this already. Particularly, if this were added and made an additional mission of our Federal Laboratory Consortium, we would be pleased to assist here. Going back to the initial philosophy that I mentioned, this would be done as a support service to laboratory management, not as something to be imposed on them from above.

To give, briefly, some very important examples of this, within the laboratories and our Federal Laboratory Consortium, we are developing on a trial basis expertise, data bases, so as to make it more easy for us to understand what is going on in other Federal laboratories, electronic mail systems from stronger communication between technology brokers and research brokers, if you will, at the various Federal laboratories, as well as developing and strengthening methods for cooperation and transfer among the Federal laboratories.

We are also working to, if you will, organize the external research community. We have already a university common interest group which involves a steering committee from a number of universities around the nation who are trying to organize the university community so as to have a better access to the Federal laboratories.

Based on some detailed studies we have done in the last few years, we will be soon initiating detailed common interest groups with large and small business as well as with trade associations.

Examples of the efficacy of this approach include the fact that in cooperation with other organizations, we work to sponsor conferences in which Federal laboratory people meet and learn to cooperate directly with industry people. Fairly recently, there was a set of such conferences in Philadelphia focusing on materials technology and in biotechnology. We at the FLC have formed basically the only interagency communication network on technology transfer, our agency liaison group.

Researchers at the Army's Harry Diamond Laboratory who, a number of years ago, initiated so-called fluidics technology and began to find that work in that area was springing up in industry as well as in the Navy and the Air Force took the lead in developing a coordinating committee on fluidics research so that people would know what each other were doing. Again, this was not a function mandated from above but driven by the individual researchers' interested in knowing what others were doing and avoiding any kind of duplication of effort.

Finally, I would like to address briefly the role of applications in strengthening science. I am well aware that it is not an intention of this task force to look in detail into the applications of science or into the innovation process, but I think it is important to note that this entire chain from basic research to applications is not a one-way chain. Strengthening the applications can turn around and strengthen basic science very strongly.

It is clear that those applications are very important to our society, from the extremes of defense to the strengthening of our economy through the productivity of State and local governments, local economic development initiatives, innovation and assistance to

small and large business, and ultimately to our national economic competitiveness. I feel that a stronger full chain from basic research all the way through applications will strengthen science in at least three ways.

First of all, the public will increase its support by seeing that the applications of science are undertaken in a systematic way rather than seeing only anecdotal results. After all, the best ideas cannot be kept hidden even if we try to keep them from commercial application. We need stronger systems to make sure that they are applied.

Second, a stronger chain will draw more talent into science and engineering, particularly within the Federal laboratories, as young people see better opportunities for themselves and a broader range of career opportunities in science and engineering, even including entrepreneurial spinoffs, whether it be from a Hewlett-Packard or from a national laboratory.

Third, applications do provide direct technical benefit right back to basic and applied science, on the one hand, through providing state of the art excellent low cost instrumentation and on the other side, providing some problem identification from the real world which can strongly inspire some areas of basic research.

In the specific case of the Federal laboratories, I feel that collaboration with the outside world can provide not only strong applications which strengthen science, but also very strong benefits right back to the mission of the Federal laboratories. Second, there is still the issue of accessibility to the laboratories for rapid applications requiring that there be stronger mandates, full-time people, active programs, and particularly decentralized authority and responsibility within the laboratories.

The awareness issue is still a difficult issue. Much of American industry still does not understand that laboratories have something that can be useful to them and understands far less that they are truly trying to be accessible. We are working very hard to change that through contacts with industry, with trade associations, with other common interest groups such as the U.S. Conference of Mayors. The basic difficulty here is that it requires individual networking to convince people outside the Government that there is something inside the Government that can be useful to them.

I think my bottom line on this subject is that strengthening the payoff of science will clearly strengthen the basic science from all standpoints of support to availability of manpower.

Again, I would like to thank you for this opportunity to address the task force, and I would be pleased to answer questions when the time comes.

[The prepared statement of Dr. Stark follows:]

STATEMENT

before the

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

Hearing on

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORTORIES

October 22, 1985

Eugene E. Stark, Jr. Sc.D.

Chairman, Federal Laboratory Consortium for Technology Transfer

and

Industrial Initiatives Officer

Los Alamos National Laboratory

Mr. Chairman,

I am grateful for the opportunity to present some views and perspectives on science in the Federal Laboratories. As requested, I will focus this statement on issues of R&D coordination in the Laboratories, changes in mission, Laboratory roles in the research community, and several additional issues that may be important in this context.

I am appearing today in my capacity as chairman of the Federal Laboratory Consortium for Technology Transfer (the FLC). This is the only organization that involves virtually all major federal R&D facilties. One unifying theme in these remarks is that the inter-Laboratory cooperation that characterizes the FLC can be a major factor in strengthening both the Laboratories' mission programs and the use of their expertise and technology in the American economy.

AN UNDERLYING PHILOSOPHY OF LABORATORY LEADERSHIP

One distinction that can be made between basic science and engineering is that innovation develops from the bottom up in scientific institutions, whereas major engineering achievements are often driven by top management. Research is performed, often self-motivated, by the individual researcher. The morale, productivity, and recruitment of good scientists and engineers is ultimately the greatest responsibility of the Laboratory technical leader, whether the title is Director, Technical Director, or Chief Scientist. The leader's performance in this arena is the most critical of his functions, and yet is the most difficult to measure.

The government's role should be to assign clear missions and project responsibilities to the Laboratories and then to support each Laboratory's leadership in fulfilling these assignments. It may be a subtle distinction, but an important one: Through his ability to influence the Laboratory's culture and the performance of its individual technical staff members, the leader already has the bulk of the authority needed to determine the Laboratory's health and performance; other Agency interactions should support, not manage, the Laboratory's leader.

As one example of the efficacy of this approach, the Department of Energy's Office of Military Application has the smallest headquarters staff per program dollar expenditure of any technical program organization in the government. It gives broad direction to the DOE weapons laboratories, which have the responsibility and stewardship to fill the nation's needs in nuclear weapon development.

R&D COORDINATION

The Task Force on Science Policy has raised the issues of coordinating effort between government and non-government R&D organizations and of preventing unwarranted duplication of efforts within the Federal Laboratories. In particular, it was suggested that the Federal Laboratory Consortium for Technology Transfer (the FLC) might have a role in these areas. (For completeness, the FLC is described briefly in an attachment to this Statement). These questions are related but should be approached quite differently.

Coordination of R&D efforts of the Federal Laboratories with other private and public research organizations can be viewed as an effort to collaborate to mutual benefit. For those individuals conducting open research (i.e. neither classified nor proprietary), it is a professional responsibility to maintain an awareness of similar work in other organizations, and to collaborate when appropriate. Much of this technical "networking" occurs in basic science, but this is much more difficult for individuals engaged in the more applied areas of research because of the large number of related projects, institutions, and results that can advance faster than the technical literature can track. In this area, the national networking of the FLC is increasingly putting private and public organizations in touch with the Laboratories and the individuals working in their areas of interest. It is particularly important that the aspects of technical networking be driven by non-federal organizations: Cooperation initiated by these outside researchers or organizations is motivated by their internal needs or perceived opportunities. The Federal Laboratories have an obligation to be accessible to these requests but the Laboratories have no reciprocal right to request, for example, access to companies' proprietary research.

The issue of duplication of effort is a bureaucrat's nightmare, but there is no evidence of major unwarranted duplication in the Federal Laboratories. A broader question that includes this issue is that of making the best use of available federal expertise and facilities. Again, the FLC provides a support service to the Laboratories by brokering and networking a Laboratory's need for access to certain facilities or expertise of other Laboratories.

In both areas addressed above, the outstanding leaders in Federal Laboratories will want to pursue networking and cooperation with other federal facilities and other research organizations. The FLC's present informal role in this arena could certainly be strengthened, but it should work in these areas only in support of the Laboratory leaders, never to be imposed on them. Or to take an alternative viewpoint, cooperation and avoiding duplication are sufficiently important to a Laboratory's strength that the Laboratory's efforts to do so should be supported rather than dictated.

The FLC is working in several areas that are strengthening its capability to provide this support. Its Far-West Region is constructing a prototype Laboratory expertise data base, to be used for inter-Laboratory networking and referrals. Based on these results, this initiative will be extended to all areas of the nation. The FLC has assembled a set of technical specialists who have volunteered to strengthen their network of contacts in the Laboratories in their specific technical areas. It has sparked the formation of a University Common Interest Group to increase cooperation and contacts between universities and federal laboratories nationwide; this model will be duplicated soon in groups with small-business and large-business emphasis. Cooperation between government Laboratories and other organizations can require an investment of time and manpower in agreement development and in determining acceptable models for cooperation; the FLC has demonstrated a significant role in transferring new cooperation methods and models among the Federal Laboratories. The FLC took the lead in establishing an Agency Liaison Group, the only inter-Agency forum on technology transfer policy and practice.

The discussion on this issue has provided a picture of some success and greater future promise. We believe that the FLC's accomplishments in stronger technology transfer will increasingly contribute to the Laboratories' broad ranges of mission activities, always provided as a service to the Laboratories.

CHANGES IN LABORATORY MISSIONS

Every effective organization has a specific, clear mission that is understood by its members even if it has not been articulated formally. This primary mission should pervade the entire organization and have a strong influence over the personality, or culture, of the organization. To ensure that the missions remain strong, they should be reviewed at least every five years.

If a Laboratory's mission changes, whether by broadening, contracting, or changing direction, a deliberate effort should be made to articulate the new mission to the entire organization. The alternative is to have the Laboratory's technical programs begin lose an important element of their vitality because they are not allied to a current mission. Worse yet, individual morale may be affected irreparably.

An alternative is to close a federal laboratory when its mission has been completed. The very possibility that this may happen can have a devastating affect on the staff even when closure is highly unlikely. Thus, long-range institutional planning for change and rapid, decisive action by Agencies in these circumstances are important if the facility is to be kept open and the vitality of its staff maintained.

A related issue is the relative roles of secondary missions such as technology transfer. To avoid compromising the impact of the pri-

mary mission, other important goals should each be the major responsibility of a member of the Laboratory's leadership. These goals can then be addressed properly, and wherever possible contribute to the Laboratory's primary mission.

ROLES OF THE LABORATORIES IN THE RESEARCH COMMUNITY

I believe that one of this nation's greatest strengths in science and technology is the variety of its R&D institutions. This allows these institutions to fit the needs and predilections of the scientists and engineers, rather than leaving our human resources with no choice of working situations. The Laboratories' roles, as contrasted with both universities and industry, reflect very different roles and opportunities for both the individuals and the Laboratories. Some of these special characteristics are:

o They often bridge the gap between basic research in the universities, and product development in industry. Development and preservation of a major technology base of expertise and facilities is a strong factor in this role.

o They can accept long-term assignments for programs or projects. Because government-sponsored work is their only source of support, these long-term programs can attract and retain top-quality technical staff.

o They can perform basic research without necessarily having an allied teaching responsibility.

o They can develop and maintain major experimental facilities and make them accessible to other users.

o Because of their government support, all unclassified results are published and they have a responsibility to the public to assure full availability of these results for commercial applications.

o The staff can have the flexibility to change technical fields and remain in the same organization; this also permits the Laboratories to develop new programs rapidly.

o Multidisciplinary and team research are more easily developed than in other sectors of the research community.

MEASURING THE PAYOFF OF SCIENCE:

This is a very difficult task. We would expect it to be much easier to quantify, for example, the results of direct technology transfer from a Laboratory to an industrial firm. The experience at Sandia Laboratories has shown, however, that the fact of a transfer can be documented; its economic value cannot, because most companies are unwilling to disclose sales or profit figures based on federal technology. Some of the Federal Laboratories have considered sponsoring such studies, but have generally conculuded that the available funds are better spent on increasing the accessibility of their technology to the private and public sectors. Even if the direct economic impact is measured, the social value of innovation is difficult to quantify; that is, the intrinsic value of a new technology may exceed the consumer's cost. Impaacts on national security are equally difficult to quantify.

One possible approach, neither comprehensive nor anecdotal, could be to ask an organization such as the Office of Science and Technology Policy to organize a study focused on a small number of research institutions and fields of science to provide an indication of the payoff.

Perphaps a more pressing issue should be to exploit opportunities to increase the payoff of science. Hearings last spring before the Subcommittee on Science, Research and technology explored the problems and potential in strengthening the economic payoff of Federal Laboratory research and technology. Those hearings indicated a significant opportunity to increase this payoff through stronger efforts at these Laboratories, involving decentralized authority but nationwide networking and cooperation.

TECHNOLOGY TRANSFER - - A BRIDGE THAT STRENGTHENS SCIENCE:

Some in the science community think of technology transfer and applications as a one-way street. In fact, the practical results of science do feed back both directly and indirectly to strenghten scientific pursuits and Laboratory missions.

Technology transfer inherently involves technical cooperation at a personal level. This cooperation can not only move technology to the public but also strengthens the originating organization. For example, cooperation with the industrial community provided major benefits in the design and construction of the Nova laser facility at the Lawrence Livermore National Laboratory. On a smaller scale, much of basic research is motivated by intriguing practical problems or oportunities, indicating the value of cooperation between researchers and technologists. Another direct benefit is improved research instrumentation that follows from commerical development of other research results.

The public's perception of the scientific community certainly influences through the political process the financial support for research. Dedicated efforts may be needed to assure the public that

the science community is a fully contributing institutional citizen--that it provides tangible value whenever it can, rather than isolating itself on a pedestal.

As addressed earlier in the Task Force's series of hearings, the continual availability of new scientific talent is crucial to the future of science. With all of our nation's social upheavals of the last 40 years, one clear result is the stronger social consciousness of many of the young. Their standards for self-satisfaction in a challenging profession are therefore broader than those for earlier generations. One result has been that many excellent science and engineering students have chosen to pursue short-term riches in the entrepreneurial private sector. At the same time, the pool of good students is expanding as artificial barriers to science careers for women and minorities have crumbled. In this atmosphere, I believe that careers in basic and applied research will be more attractive as the "connection" of science to society becomes stronger-- as the results of research become fully pragmatically available for commerical use to society's benefit; and as specific technical needs in the public and private sectors provide greater relevance to basic research endeavors. This potential for broadened satisfaction and opportunity is not limited to new scientists. It can be a constant source of renewal and motivation for science and engineering professionals at all stages of their careers.

A SUGGESTED INITIATIVE TO STRENGTHEN AMERICAN SCIENCE

Any major change in the relationships or aims of of the U.S. science community could occur only slowly, due both to individual and institutional attitudes and traditions. However, the nation's need for rapid industrial innovation, part of which is driven by the coupling of research to application, has not been greater since the end of World War II. New directions or emphases in this area cannot realistically be expected to solve the problems of budget deficits or balance of trade. But the scientific community can contribute significantly more then it does today, if it is open to a reaffirmation of its substantive role in society.

Though the efforts of the President's Science Advisor and other leaders in the Administration, the Congress and the techinical community, the issues of financial support and areas of emphasis are being addressed actively. What remains to be accomplished is an effective, grass-roots effort to couple science to applications with particular regard to the Federal Laboratories.

I was pleased to present a more detailed exposition on this subject to a hearing of the Science Research and Technology Subcommittee on May 22, 1985. The main points are summarized below:

o Stronger coupling of science to applications stregthens science through: institutional and individual respect that follows from substantive contributions to the nation's economy and security; an enhanced lure of science for talented students; greater opportunities for researchers' professional satisfaction; and the increased commercial availability of state-of-the-art instrumentation.

o The coupling of research to applications should be an integral part of each R&D institution's mission; depending on the institution, it may be a primary or a secondary mission. In any case, it should be recognized and accepted by the leadership and technical staff of each institution.

o There should be a clear national mandate and awareness of this strengthened coupling. The mandate will provide a clear signal to the research institutions; a greater awareness is needed in all sectors and sizes of business and industry so that they will seek their share of the bounties of science.

o In at least this area of endeavor, the authority and responsibility to engage in institutional cooperation and technology transfer should be decentralized at least to the individual institution. This is important because the recognition of potential innovation most often occurs at the working level and can be nurtured only at that level.

o Wherever possible, new or strengthed coupling of science to technology, therefore institution to institution, should be driven by the private sector: by large businesses, small businesses, trade associations, as well as by those state and local governments seeking greater economic development opportunities.

o In return, the research institutions should be properly accessible to these requests for cooperation. Non-government institutions will handle this increased expectation in their own ways. Within government facilities, grass-roots networking for both technical cooperation and for technology trnasfer should be strengthened.

ATTACHMENT

THE FEDERAL LABORATORY CONSORTIUM FOR TECHNOLOGY TRANSFER (FLC)

The FLC is a partnership of over 325 federal research and development laboratories and centers. Members are responsible for 85% of all federal laboratory research and development. Its goal is to provide the environment, the operational structure and the transfer mechanisms to support the fullest domestic use of unclassified federal technology. The Consortium's role is to assist its member laboratories in:

o Development of effective technology transfer methods and mechanisms;

o Transfer of federally developed technology to domestic public and private organizations;

o Application of federal talent, where appropriate, to domestic public and private needs;

o Establishment of networks with the rest of the technical community to refer requests or engage in cooperative efforts.

The FLC provides the only interagency, interlaboratory forum on technology transfer, and therefore facilitates significant cooperation among these institutions. Important results include: training of individuals newly assigned to technology transfer; the transfer of new technology transfer or cooperative mechanisms among the laboratories; and increased effectiveness and efficiency of each laboratory's transfer program through national outreach activities and efficient brokerage of technology needs and opportunities. Particularly as laboratories begin new or expanded efforts in technology transfer, this interpersonal network of experienced individuals has been a valuable resource for these laboratories in developing programs that

are both effective and complementary to their organizational cultures and missions. This cooperation has also proven directly valuable to the laboratories' missions through interlaboratory cooperation and laboratory-laboratory technology transfer.

The FLC is organized into six regional groups, each with a designated Regional Coordinator. These Coordinators form the FLC's operational backbone by serving both as (a) primary referral points in the network, brokering requests from their regions to the appropriate laboratories; and (b) organizers of special regional projects and efforts to market the availability of technology transfer to industry, state and local governments and universities in their areas. The FLC is governed by its member laboratories' appointed representatives through an elected Executive Committee; it has an advisory committee drawn from representatives of users. It holds national meetings semiannually as a forum for formal and informal exchange of information among member laboratories' representatives, and representatives from state and local government, universities, industry and Congress.

Networking

Because it represents a large resource of federal laboratories, the FLC can establish relationships with many organizations and groups representing potential users of laboratory technology.

Memoranda of Understanding - Several formal Memoranda of Understanding have been generated between the FLC and entities that share its interest in technology transfer. Existing agreements are with: Training Resources and Data Exchange; the Department of Commerce; US Conference of Mayors; Public Technology, Inc.; Florida Small Business Development Centers (and the Southeast Region, FLC); NASA Industrial Applications Center (and Farwest Region, FLC).

For the several states and areas without major federal laboratories, the FLC network can provide a unique opportunity to make federal technology and assistance available through the FLC regional coordinators. Two examples of enhanced interactions with such states have resulted from holding FLC-sponsored meetings: As a result of an FLC semiannual meeting in 1983 in Biloxi, numerous contacts and transfers were made between laboratories across the country and state agencies in Mississippi. At this FLC meeting, the representative from the Army Aviation Systems Command in St. Louis met a university professor who is now the science advisor to the Governor of Missouri. As a result of this contact, this representative will participate in an economic development conference sponsored by the Governor's office.

Because federal technology transfer is very resource limited, this mechanism has not been extended to all such states and locales. Special efforts by out-of-state laboratories have been made, for example, with Missouri, Oklahoma, Texas, Oregon, Mississippi, Hawaii, Arizona and Nevada.

COMET Electronic Mail System - Sandia National Laboratories have provided access to use their COMET Electronic Mail System to the FLC Executive Committee and representatives in the Sandia-coordinated Mid-Continent Region. It is used to circulate requests for information and assistance from FLC clients to the six regions via the Regional Coordinators.

One example illustrates its utility. The ORTA at Argonne National Laboratory relayed a request for information on electroluminescent signs to regional coordinators via COMET. Ninety minutes later, the ORTA at the National Bureau of Standards had relayed the request to a local expert who telephoned the requestor in Minnesota that day.

Examples of Networking Results - The Naval Underwater Systems Center heard about a computer software learning program developed at the Navy Personnel R&D Center. The program was created to teach vocabulary and literal comprehension specifically for Navy terminology and technical reading, but can be used to enhance those skills in any content area. NUSC decided to test it in a local school system for which their volunteer service was helping to develop a computer curriculum and computer requirements design. A workshop at NUSC, given by the NPRDC developer of the program, was attended by the Army Human Engineering Laboratory representative and he is now experimenting with it for a Reading Skill Improvement Program for the National Commission on Libraries and Information Science and the Baltimore County Public School System. To that end, a workshop was held at Harry Diamond Laboratory to train volunteer teachers to use the program.

Harry Diamond Laboratory had contact with Montgomery County, Maryland through its volunteer effort. A problem was identified in public works. The county needed information on waterproofing older (historic) brick buildings, and was especially interested in polymer coatings. HDL arranged for: a) advice from National Bureau of Standards on protection of brick buildings and b) evaluation reports on polymer coatings from the Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

A volunteer effort to provide an energy assessment for the East Lyme (CT) High School had direct benefit to a newly purchased industrial plant in Cambridge, Ohio: A request for assistance from a local assistance group, TRACES, to the Wright-Patterson Air Force Base was networked to the Naval Underwater Systems Center, which provided contacts on the project at East Lyme.

The Naval Air Development Center, PENNTAP and the FLC cooperated in transferring the Navy Preventive Maintenance Program to local governments through workshops and other assistance.

Through the FLC, the Naval Air Development Center (NADC) compiled information from three other agencies' laboratories on waste management, disposal and incineration for energy production. NADC is working with a consortium of townships in Pennsylvania to demonstrate and transfer this technology.

Development and Replication of Transfer Methods

Developing a technology transfer project within a laboratory can be time-consuming in addressing all operational and policy issues. The FLC assists both in developing transfer methods and in documenting successful approaches and transferring them to other laboratories.

Technical Volunteer Services - FLC member laboratories such as the Naval Underwater Systems Center (NUSC), along with several other public and private organizations, have taken the lead in establishing Technical Volunteer Services, available to communities surrounding their laboratories.

The FLC, with support from the Departments of the Army and Navy, the Administration on Aging, and individual laboratories, has been the vehicle for providing information, encouragement, training and assistance in establishing a TVS in all interested laboratories.

The FLC holds informational and training sessions on the intricacies of establishing volunteer services at its semiannual meetings. The FLC provides the forum for exchange of information and experiences, as well as the sharing of training aids among the laboratories.

The extension of this concept to other laboratories through the FLC has resulted in nine new programs in the past two and a half years.

Technical volunteers from the Naval Underwater Systems Center are working on a variety of aids for the physically handicapped. A task force of employees from NUSC's New London Laboratory are adapting toys and mobility vehicles for young (eighteen months to three years) cerebral palsy victims. The ability to use the adapted toys allows the children to gain some of the learning experiences that benefit unimpaired children. Members of NUSC's Newport Laboratory staff have developed a computer software program and adapted peripheral devices to assist young adults with cerebral palsy in improving their fine and gross motor control. These volunteer efforts have provided custom computerized communications systems to over 20 profoundly disabled individuals.

Expertise Data Base - The FLC, in cooperation with the Naval Material Command, supported development of a Technology Transfer Data Base at the Naval Weapons Center. Within the laboratory, it is used to locate individual technical experts for both mission requirements and for response to technology transfer inquiries. Although this detailed information is available only within the laboratory, for security and other reasons, a summary data base will be made available to other laboratories as a resource base for technology transfer referrals. Ultimately, through the FLC, it could be an important resource for all federal laboratories' internal operations, other mission needs, and technology transfer.

Technology Transfer Program Planning - The US Forest Service has developed a technology transfer program planning process to ensure rapid transfer of its developments in each program. Information on this process has been transferred to other laboratories through the FLC for their use.

Federal Laboratories Resource Directory - The FLC has taken the lead in proposing an interagency effort to develop a directory of federal laboratories, their major program areas and key capabilities.

The directory is intended to be an automated data base with inputs from the participating agencies. Two categories of applications are envisioned: information dissemination and laboratory management. A committee of FLC, Agency and CUFT representatives is working on locating a funding source and agreeing on specifications.

Marketing

Developing interest in potential users of federal technology, and making the links between the source and user of a technology are formidable tasks. These are assisted by the FLC through nationwide outreach activities (brochures, exhibits, articles), and the networking functions described earlier.

FLC-Industry Workshops - One need in effective networking is to provoke efficient communication between disparate groups. In cooperation with Technology Transfer Conferences, Inc., three laboratory-industry workshops have been held. Each workshop gives exposure of 10 laboratories to 30 major companies. Most laboratories report follow-up interactions based on these workshops, which are especially useful to smaller laboratories that are not known well by industry. Two such

workshops focusing on new materials and processes and agricultural and biotechnology were held in Philadelphia earlier this month, attracting substantial interest of both industry and the Federal Laboratories.

FLC-University Common-Interest Group - The FLC recently established a steering committee of individuals representing universities from five states to develop an FLC-University Common Interest Group. It will work to develop a national network of cooperation within which universities and federal facilities can cooperate in technology transfer; it will also strengthen FLC cooperation with universities through existing university-based organizations, such as the National Association of Management and Technical Assistance Centers and the National Productivity Network.

This is an extension of efforts in the FLC's Far West Region members in developing cooperation with the California State University campuses and the community colleges in California to develop a technical assistance network analogous to the Ohio Technology Transfer Organization.

Similar Common-Interest Groups will soon be formed with small business and large business.

Recognition-

Awards for excellence in technology transfer were established in 1984 to recognize laboratory employees who have been responsible for important transfers, but for whom technology transfer is not a major job responsibility. These and awards for FLC representatives and others help provide recognition and incentives for effective technology transfer.

Training

Through the FLC, both formal and informal training assists individuals new to technology transfer or those interested in new methodologies. About 25 new laboratory representatives receive orientation at each FLC semiannual meeting. Special training sessions onestablishment of volunteer programs have been presented. Sessions have been held at FLC meetings to introduce such subjects as trade association interactions, patents, issues in militarily critical technology, the needs of the aging, university interactions, state and local economic development, and technology transfer between federal R&D organizations.

The FLC's network also provides valuable person-to-person advice both to assist new technology transfer professionals in their new programs and to assist each other with ideas, perspectives and problem-solving in specific technology transfers.

Mission Benefits

Effective technology transfer professionals are aware of the technology, expertise and needs within their own laboratories. Through the FLC's forums and network, there are opportunities for laboratory-to-laboratory transfer and cooperation for direct mission purposes. In addition, in many technology transfer situations, particularly with industry, there is a two-way transfer that enhances the labortory's technology base for mission work.

EPA Region III Office (Pniladelphia) working through the FLC, surveyed technical resources that could be used in emergency hazardous/toxic waste problems. As a result of this survey, EPA was able to utilize special equipment developed at the Naval Explosive Ordnance Development Center, Indianhead, Maryland to locate a large group of buried barrels of hazardous waste at a site that became designated for Superfund activities.

Other Support Activities

FLC/Agency Liaison Group - In 1983, the FLC organized an Agency Liaison Group. This group has become a regular interagency forum on technology transfer issues, policies and methods. It also provides the FLC with input from its member laboratories' parent agencies on improving its services.

Federal Laboratory Directory 1982 - FLC cooperated with National Bureau of Standards' ORTA, in the preparation of the directory, NBS Special Publication 646 issued in 1983. It contains various summary data and an information sheet on each laboratory.

NBS has disseminated 3,000 copies. Recipients were all federal laboratories, 700 industrial organizations, policymakers in the Agencies and Congress, and repository libraries. An updated edition is in progress.

Mr. FUQUA. Thank you, Dr. Stark.
Dr. Hess, we will hear from you at this time.
[A biographical sketch of Dr. Hess follows:]

DR. WILMOT N. HESS

Title: Director, National Center for Atmospheric Research, Boulder, CO.

Education: B.S., Electrical Engineering, Columbia University, 1946, M.A., Physics, Oberlin College, 1949, Ph.D., Physics, University of California At Berkeley, 1954.

Honors, Offices an Societies: 1965—Arthur S. Fleming Award for one of the ten outstanding young men in the Federal Service, 1969—AIAA G. Edward Pendray Award, 1969—NASA Group Achievement Award, 1970—Honorary Degree, Doctor of Science, Oberlin College, Ohio, 1971—ASTM Thomas A. Marshall, Jr. Distinguished Lecturer on Research.

Past Associate Editor of *Journal of Geophysical Research, Journal of Atmospheric Sciences, Review of Geophysics, AIAA Journal, Moon and Space Science Reviews.*

1970–1976—Professor Adjoint, Department of Astro-Geophysics, University of Colorado, 1976—Elected to National Academy of Engineering, 1978—NOAA $1,000 Award for Special Achievement, Fellow, American Geophysical Union, Fellow, American Physical Society, Fellow, American Meteorological Society, and Fellow, American Association for Advancement of Science.

Technical Papers: Author of 87 scientific papers; author and/or editor of six books or special reports.

Experience: 1954–1959—Staff Member, University of California, Lawrence Radiation Laboratory, Berkeley and Livermore, CA.

1959–1961—Leader, Plowshare Division, University of California Radiation Laboratory, Livermore, California. Dr. Hess directed a division doing studies on industrial uses of nuclear explosives for building harbors and canals, recovering energy from underground explosions, producing oil from oil shale in situ, and other projects.

1961–1967—Chief, Laboratory for Theoretical Studies, NASA Goddard Space Flight Center, Greenbelt, Maryland. Dr. Hess directed a division of astronomers, plasma physicists, geologists, atomic physicists and geodesists doing theoretical studies on a wide variety of space science problems. He carried out a personal research program aimed at understanding the origin and characteristics of the Van Allen radiation belt.

1967–1969—Director of Science and Applications, NASA Manned Spacecraft Center, Houston, Texas. Dr. Hess planned and conducted continued programs of investigations in the areas of earth and lunar science; provided environmental data required to support spacecraft and mission design by planning and conducting programs involving the application of space systems and operational capability to the analysis and evaluation of the earth's resources; planned and conducted continuing programs of investigation in the area of meteorology with manned spacecraft; conceived, developed and integrated experimental instrumentation and equipment for use in the scientific and applications program; supported principal investigators in the development, integration, and conduct of experiments; planned and operated the Lunar Receiving Laboratory and other facilities required in support of programs; supported astronaut training in the areas of science and the conduct and operation of experiments; and provided space environment data and operational support of experiments during manned space flights.

1969–1980—Director, Environmental Research Laboratories, National Oceanic and Atmospheric Administration, Boulder, Colorado. Dr. Hess directed the activities of 11 research laboratories and a flight facility, employing about 1,400 people. These laboratories perform the major portion of the research in NOAA and work closely with the National Weather Service and the National Ocean Survey to bring the results of research programs into operational programs. The laboratories work mainly in the disciplines of meteorology, oceanography, geophysics, aeronomy, and space sciences.

For more than one year (1977–1978), Dr. Hess was the acting general manager of NOAA, having resources of $800 million and 13,000 people. In this capacity, he was responsible for many of the day-to-day decisions to keep the organization moving, especially those dealing with resources allocations, program planning and budgeting, and transactions between the various line components.

1980–Present—Director, National Center for Atmospheric Research, Boulder, Colorado.

STATEMENT OF DR. WILMOT N. HESS, DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, CO

Dr. HESS. Thank you, Mr. Chairman, for inviting me to testify at this hearing on science in the mission agencies and Federal laboratories.

With your permission, I would like to submit my testimony for the record and give a short summary of it.

Mr. FUQUA. Yes. We will make it part of the record.

Dr. HESS. Thank you.

I have worked as the director of several Government civil service laboratories in NASA and in NOAA. I have also worked as the director of contractor laboratories. I am now at the National Center for Atmospheric Research which is vaguely a contractor laboratory but has various differences from the standard contractor laboratory.

I have a certain amount of perspective in this business seeing problems that exist for the operation of Government laboratories. I would like to tell you my personal views on some of these problems.

First, what does it take to make a good research laboratory? I would suggest the following set of conditions. First, you have to have an interesting research program that provides a challenge for a scientist working at that institution. This was a subject Mr. Ritter was talking about earlier. Does the organization or agency have a mission which provides a cleanly defined program that is exciting to the scientist working there? Then, you have to have a group of stimulating scientists, a large enough group, so that one can knock ideas around inside the group so that there is somebody to talk to about the things that you are working on that you consider a peer, a certain critical mass, then.

Then, you need a long-term, stable program. The vagaries of Federal funding make that difficult in certain research laboratories. Not only does it need to be long term, and by that I mean more than 3 years but 5 or 10 years in length, but it has to be in some way insulated from the political process so that the laboratory is allowed to operate as a research laboratory without having to contend with political pressures that move it in directions which are not those natural for a research organization.

You need local planning of the research program. That should be done inside guidelines set up by the agency, the sponsoring organization, that says this is the field of work you should work in, here are the problems we have as an agency. Inside that set of guidelines, the local organization should design its research program.

You have to have competitive salaries in order to attract and retain key scientific personnel.

I would submit that is a list of conditions that you must have to make a good research laboratory. I would say that almost all of those are violated when you look at the Federal system and try to see if it is possible to make a good research laboratory, to have a good research laboratory, inside the Federal GO–GO, Government-owned, Government-operated, laboratory system.

The first problem I would suggest is a serious one is the personnel system. By that I mean civil service and the related Senior Ex-

ecutive Service which is not competitive in salaries. The salaries that you are allowed to pay to a key scientist inside civil service are at least 30 percent, maybe 50 percent, below salaries that you ought to be allowed to pay if you are going to be able to retain key scientists in your organization.

The civil service system does not motivate a good employee. The system of rewards is almost completely lacking for a system that you would like to have in place to tell a person who is doing good work he is doing good work and to show it by giving him a bonus, by some other award that allows the individual to understand he is performing especially well.

The system of bonuses that was early promised in the SES system has turned out to not work at all. There are so few of them that they do not constitute seriously a motivation for a person working inside SES.

The civil service system also does not allow the manager or director of a laboratory to discipline a poor employee. It is almost impossible to withhold an in-grade promotion. It is very difficult to fire a nonproductive employee.

If you want to have a bad morale system, develop a system where poor employees are put in the same environment with good employees and there is no difference in the way management treats those two groups. That guarantees bad morale.

The personnel ceiling system imposed by Government is a nuisance or worse when looked at from the management of a laboratory. The fundamental control you should put on a research laboratory in the way of resources is a budget. Given the budget, you should try to make sure that that money is used properly to carry out the purposes that the laboratory has been set up for best, but don't put any artificial impediments in the way of the laboratory. Personnel ceilings, wage-bulge arrangements, travel ceilings, any secondary constraints on the way that the money is spent will almost automatically mean it is spent less efficiently and there is waste of money.

Inside the civil service system, there is called for an annual work plan. That work plan is essentially useless and a waste of time for people in research laboratories. You can't lay out a work plan that thoughtfully analyzes what a research scientist is going to be doing the next year.

You can suggest directions of work, but in saying what he should do and what he should accomplish over that period of time is essentially completely opposite to the concept of the word research. I would suggest that the whole concept of work plans should be done away with inside research laboratories.

Aside from that, I guess the civil service system works well. [Laughter.]

The recommendation that comes out of this is the same as the recommendation coming out of the Packard Committee, that there should be put in place a personnel system outside civil service like that recommended by the Packard Report for the operation of Government laboratories. I don't mean to say that the Government laboratories should be put into the private sector and made non-Government. I don't think that is probably the right solution.

But there should be a different personnel system put in place and that different personnel system should have a separate mechanism for setting salaries to make those salaries competitive with the outside world, with the peer group that you are interacting with outside, and the personnel system should have proper motivation built into it and proper disciplinary action built into it. You should be able to fire a nonproductive research scientist. You should be able to fire a laboratory director who is not doing his job well.

The second problem I would put to you is the matter of long-term stability. I think it is necessary to get away from the matter of having 10 or 20 percent up and down in budgets on a yearly basis for any research laboratory. That kind of instability shows in the staff and it means you will not retain your best people if they don't feel that there is a program that they can see through.

A typical program for a research scientist to accomplish something significant will take him 3 years, maybe 5 years. As a team effort, it might take 10 years to develop a large piece of equipment, a large program to go on a super computer. If it looks as if he is only going to be allowed 1 or 2 years because of the vagaries of funding, you are unlikely to retain that person.

I would suggest you ought to have at least 3-year funding and that this ought to be on some kind of a rolling basis where it is renewed before the end of the third year so that the continuity is then in place rather than at jeopardy at the end of the third year. You should build inflation into that 3-year contract so that the program is not going down hill as it moves forward.

Second, as a matter of long-term stability, it is necessary to insulate the laboratory from the political process. Now, a way to do that is to put at least one layer of management in between the laboratory and the political officers of the agency. That means it is harder for the political problems to be passed down. You tend to sort them out as the laboratory director and his boss do their jobs.

The next problem is the quality of research. It is clear that there are certain research laboratories attached to the Federal establishment that aren't as good as some other research laboratories. It is also clear that there are some world-class research laboratories in the Federal system, and we should all be proud of that. I would submit to you that it would be very difficult today to start a laboratory and grow it to world class in a decade with all the impediments in the system.

How do you guarantee quality of research? How does the sponsoring agency find that it has a good product and its people are doing good research?

The suggestion that Mr. Packard put forward of having peer review is clearly the way to do this. Have an external organization come in and review for quality. We have this system in place at NCAR. I have used it in the past at NOAA.

The National Academy of Sciences does this kind of peer review for several agencies of Government and does it well. They put together a peer review committee made up of notables of the field that is to be reviewed, representatives of universities, of Government laboratories, of industry, and that team will come in and review both the work of the last 2 or 3 years and the plans for the

short-term future. In that way, you get a feeling that the work carried out is of high quality.

The research program we have in place carries out that review down to each Ph.D. scientist's work on a 3-year basis. I feel that is very satisfactory. It provides us with a completely clear look at what is going on inside our laboratory as viewed from outside, how good it is, where weak spots are.

I think that review should be carried out both for the director of the laboratory and for the sponsoring agency.

One other problem, the matter of procurement. Inside the Federal system of civil service laboratories, procurement using the Federal procurement regulations is a very difficult business. I have recently seen an example of this where an agency I am familiar with got the money in their budget in 1980 to procure, not a supercomputer, but a medium-sized computer, and they didn't get it in place on the floor until 1985, 5 years later. At least half of that time was strictly the result of the Federal procurement regulations.

In our laboratory and laboratories outside the Federal system that don't have to use those procurement regulations, I think we do an honest, honorable job of procurement. It is audited regularly. We don't have the laborious scheme you have to go through inside those regulations. I would submit you ought to do something to try to get rid of those, not have that impediment in front of the laboratory director.

In summing up, then, I agree very completely with the findings and the recommendations of the Packard Report. I think that the views that are put forward there on making an independent personnel system, making sure that you have quality peer review are very important.

I have recently seen a copy of the newly introduced Federal Science and Technology Revitalization Act that your chairman put in. I support very strongly the objectives of this bill. I might have a few questions about particulars in it, but I think that goes a considerable distance to solve some of the concerns I have in the system although not all of them. That helps very much in the area of personnel in moving toward a system which would allow Federal Governments to work well. There still would be some other problems left over.

I thank you, Mr. Chairman.

[The prepared statement of Dr. Hess follows:]

TESTIMONY OF DR. WILMOT N. HESS
DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH*
BEFORE THE HOUSE OF REPRESENTATIVES SCIENCE & TECHNOLOGY COMMITTEE
TASK FORCE ON SCIENCE POLICY ON OCTOBER 22, 1985

Thank you, Mr. Chairman, for inviting me to testify at this hearing on "Science in the Mission Agencies and Federal Laboratories." I have worked at government Civil Service laboratories (government-owned government-operated laboratories) at NASA Goddard Space Flight Center and NASA Manned Spacecraft Center and NOAA Environmental Research Laboratories. I have also worked at contractor laboratories (government-owned contractor-operated laboratories) at the Lawrence Berkeley Laboratory and the Lawrence Livermore Laboratory and I am now at the NSF-sponsored National Center for Atmospheric Research.

Because of my background I have some strong feelings about the problems of developing and running a research laboratory, both as a government-operated Civil Service laboratory and as a contractor-operated laboratory. In mission agencies such as NOAA, NASA, DOE, EPA, there are substantial research programs, some of very high quality and some of medium quality. It is perhaps surprising that the general quality of the research programs is as good as it is given the constraints under which these agencies must operate.

First, let us look at what it takes to make a first-class laboratory and then look at several reasons why it is very hard to achieve this goal in government mission agency laboratories.

---

* sponsored by the National Science Foundation

What Makes a First Class Research Laboratory?

First, you must have an interesting research program. This, of course, depends upon the mission of the agencies involved. Many government organizations have program responsibilities in areas that involve them in the cutting edge of physics, chemistry, engineering, and/or environmental science. Let us assume the mission of the laboratories we are interested in is clearly enough stated and has a strong scientific component so that the reason for the existence of research laboratories in this agency is obvious and the general area of research work should be exciting and productive. What else is needed?

A second requirement is that there be a group of stimulating scientific colleagues to work on these problems. Few things will discourage a first-class scientist more than not having a scientific sounding board. You must have a critical mass of high quality research personnel to make a good lab function. This of course takes a period of time to develop.

A third requirement for a high quality laboratory is a long-term, stable research program. The program that changes objectives every two or three years, that moves with the political wind, and that does not allow a research team to seriously challenge important problems over the long-term will not prosper. Most significant research programs take several years to produce useful results. It is not surprising for a group of scientists developing a complicated numerical model of the atmosphere, for example, to work a decade or more in the development of a high quality product. This time scale is probably similar in many other disciplines.

Fourth, one needs local control of program planning. No strong research laboratory is centrally planned from a Washington headquarters office. Essentially all good research ideas percolate up from the working scientist to management, and management then has the job of sorting out the best ideas and sculpting the best programs of work on agency problems. Centralized planning as practiced in the Soviet Union does not produce good agricultural output or good factory production, and it certainly doesn't produce good research programs.

Fifth, a Director of a high quality research laboratory should almost always be a scientist or engineer who is familiar in detail with the work done in the field of research of the laboratory. Professional planners or business people generally do not do as well because they don't understand or have experience with the science involved, laboratory structures, or how to develop a research strategy.

And sixth, a strong research staff must be paid salaries that are competitive with the other parts of the research establishment with which they interact. If the principal source of recruiting for scientists is from universities, for example, then you must pay salaries that are competitive with that environment. If the recruiting arena is in private industry, you must pay that level of salary. If you don't, you won't keep your team together very long.

If the research laboratory has all of the above ingredients then you must give it time to produce important results. It takes a decade or more

to grow a world class research laboratory. There are world class laboratories in several of the mission agencies and they are laboratories that have been nurtured and supported for decades.

If these criteria accurately describe what it takes to make a good research laboratory, how easy is it then to develop and maintain a first class lab in a mission agency of the U.S. Government? There are enough hurdles put in the way of a government-run organization that it is not surprising there aren't more of them. What are these road blocks? And how can we overcome them?

Personnel System

The personnel system used by most government laboratories is the Civil Service System. This has many serious shortcomings. It is not run from the viewpoint of developing or maintaining a good research laboratory at all. I am not sure it works well for any component of government but it clearly works very badly for research scientists. Here are some of the things that are wrong with it.

1. Civil Service salaries are not competitive for good research scientists. They lag considerably behind salaries for senior university faculty and even farther behind salaries for senior research personnel in high tech industries. In the laboratory I direct, the National Center for Atmospheric Research, which is not Civil Service, we have trouble keeping our salaries competitive with universities, and sometimes lose key research scientists to university jobs paying considerably more than we can. Our salaries are higher than Civil Service salaries for most research positions,

so government laboratories will clearly have more trouble than we do. If you want to get, and hold, good research scientists you must pay competitive salaries.

2. The Civil Service salary system does almost nothing to motivate the employee. If a scientist does an outstanding job on some particular project, can his lab director reward him appropriately? The answer in many situations is no. The scientist's salary is embedded inside a system which is completely inflexible. It recognizes no differences between special scientific disciplines in high demand - for example, systems programmers, or research physicists with years of experience - from people with skills much more widely available.

When the senior executive service (SES) was started, it promised bonuses and awards to high performing individuals which would have been a considerable motivating factor. Now that the system has been in operation for some years, it has become apparent that there are so few of these awards available, even for the really deserving people, that they do not constitute a realistic motivation at all.

The Civil Service System also discourages a manager or lab director from trying to hold back a poorly performing employee. If a person is not performing well, his supervisor should be able to withhold an in-grade pay raise. Withholding an in-grade pay raise is now so difficult that they are essentially automatic. If an employee is really performing poorly and a supervisor thinks he ought to get rid of him after the probationary period is over, this takes a lot of doing. There must be an extensive period of collecting information to show the employee is not performing adequately.

Then there is a very lengthy review process including hearings before the Merit System Protection Board. This system is so onerous that a supervisor, rather than trying to use it, frequently decides to put the poorly-performing employee in a corner somewhere where he can do no harm and forget about him. This is bad for the morale of the entire organization and a waste of taxpayers' money.

3. Personnel ceilings and grade-bulge restrictions should not apply to research laboratories. The primary control on a research program should be the budget. Given a certain level of funding from the mission agency, the laboratory Director should have the freedom to decide how many people are needed to do the job and what the mix of junior and senior people should be. Any arbitrary limits on personnel simply mean the job will be done less well.

4. In the Civil Service System, each supervisor writes an annual work plan for each employee supervised, laying out what is expected of that employee during the next year. This is absolutely useless and wastes a lot of time for managers and scientists in research laboratories. It may be useful for people who are in repetitive tasks in manufacturing, but it is just waste motion in a research environment. It ought to be done away with.

As you can see, I feel strongly the Civil Service System is very bad for research laboratories. What can be done instead?

A separate scientific personnel system, independent of the present Civil Service System, should be set up for research laboratories. Such a system already exists in many laboratories operated by the private sector for the government. It also seems possible to have such a system inside a government-owned, government-operated laboratory. The Naval Weapons Center at China Lake has experimented with such a system and it seems to work. This personnel system should be under the control of the research laboratory with appropriate oversight by the sponsoring mission agency. It should set salaries competitively. It should provide motivation so the managers could reward good performance and get rid of poor performers. I know such a system will work because we use this system at our NCAR laboratory.

Long-Term Stability

How can we make a research laboratory have the appropriate stability to allow it to carry out a strong research program? One essential ingredient in this stability is that the budget of the laboratory not fluctuate violently. If you have a ten or twenty percent reduction in the budget of a lab for a couple of years, and then a ten or twenty percent increase, this kind of instability will cause serious problems with the senior research staff. They will be inclined to move somewhere else where the budgets ARE more stable. The way to achieve stability would be to have multi-year funding for research laboratories. If it takes three years or more to get substantial results from a research program, give the laboratory Director money for three years. Include enough in the second or third years to pay for inflationary increases. All of these funds should be no-year money so that they can be carried over into the next year. In this way you prevent the silly scramble to spend year-end funds, which is often a waste of public funds. Then at the end of the three-year period, carry out a review of the

laboratory and find out if the work carried out is of high quality and should be continued. If it is not, make appropriate changes. If it is deemed to be high quality, write another contract for funding the next three years. In this way the short-term fluctuations in funding could be done away with. The laboratory would still have the possibility of responding to new program directions which were not anticipated at the beginning of the three-year period by going back to the mission agency for incremental funding. But the base funding of the laboratory would be stable over the three-year period. The problem with the system now is that one-year funding with its inherent fluctuations often causes serious difficulties for the government laboratory where research programs require five years or more to come to maturity.

I think it would be a wise idea for Congress to move toward multi-year funding for all government agencies, but I think it is especially important for a research laboratory where stability is essential in order to carry out long-term programs.

A second ingredient in the long-term stability need has to do with insulation from the political processes in Washington. Basic research programs take years to produce meaningful output. To have the laboratory objectives or research program pushed around every year or so by some new political pressure will help to guarantee loss of productivity and waste of public funds. The organizational structure of a mission agency should have at least one layer of insulation between the Director of the research laboratory and the agency's political officers in Washington who must respond to these political pressures.

Procurement

Another factor affecting many research agencies concerns the extremely laborious and long procedures necessary to procure major equipment items for the research programs using federal procurement regulations. It now takes an average of two years from initiation of procurement until the laboratory has a medium-size computer in place. With such delays built into procurement, it is not surprising that some laboratories have trouble meeting deadlines. The procurement staff should work directly for the research laboratory and not for a central agency office in Washington. The procurement specialists should be familiar with scientific problems and the general program of research of the laboratory. One way to solve both the matter of insulation from the political process and the problems with federal procurement policy is by having the laboratory operate either by the private sector or in some other system not directly run by a federal agency and hence subject to politics, or to federal regulation affecting personnel and procurement procedures.

Peer Review and Peer Interaction to Assure the Quality of the Research Program

How can the mission agency make sure that it is getting the public's moneys' worth from a research laboratory? If the laboratory operates rather independently, as I have suggested, will it do the kind of research that will help carry out the agency's mission and will it be high quality research? There is a simple, straightforward way to make sure the program is appropriate to the agency's mission and it is of high quality: have an external review of the agency's program conducted by scientific peers every two or three years. The National Academy of Sciences (NAS/NRC) has carried

out this review process for a number of agencies in the past. It could be done by other independent scientific organizations, but the NAS does it well. The NAS puts together a review committee made up of highly qualified research scientists who have broad views of research and its relationship to the missions of the agency. They are recruited from universities, not-for-profit organizations, and industry, and represent a broad spectrum of the scientific thought in a specific research area, and produce an independent and insightful evaluation. Such a review committee will tell management if the research lab is not performing as well as they think it should be. I have been through these reviews carried out by NAS. They are tough, but they are fair and they are extremely useful to management. The management can decide whether part of the program or the personnel involved should be altered, and find out if first class work is being done or not. Some mission agencies do not use this external peer review process and in some cases it shows. The NOAA Environmental Research Laboratories used to have NAS reviews but they do not now. I think they should return to the old system.

Another extremely important characteristic of a good research laboratory is that its scientists interact with those working in its subject areas in other organizations such as universities. Most of the basic research work in the United States is done outside government laboratories, a large portion by universities. It is essential that a good laboratory keep in close contact with the strong research groups in its subject area. This means writing research papers published in the refereed journals. It means attending the research meetings of the appropriate national organizations in the field - the APS, ACS, AGU, etc. But above all, it

means working collaboratively with the leading scientists in the field. This means having university scientists spend sabbaticals at a government research laboratory. It means having post-doctoral fellows from all of the important universities spend a couple of years there also. These people bring in many new important ideas in research. Without this new blood coming from the universities, an organization tends to get intellectual "hardening of the arteries." The NAS review committee should look very hard at the collaborative research program being carried out by the mission agency laboratory. The more of this the better. Probably as much as ten percent or more of the budget of the research laboratory should go directly to sponsor these collaborative activities. The NAS peer review committee should comment on the quality and quantity of this collaborative effort.

Control by the Sponsoring Agency

The image of the productive government research laboratory that I have drawn is one with a good deal of independence. There is bottom-up planning; local control of personnel, salaries, and procurement; and outside review and interaction to assure the quality of the program.

Now then, how does the mission agency make sure that a mission laboratory is doing something useful for that agency?

1. The mission agency should set general objectives for the laboratory program. These objectives should be to help develop knowledge in particular areas or on particular broad problems, in order to help the agency carry out its mission. You wouldn't expect to find an EPA research laboratory working on cosmology or archaeology. You would expect it to work in broad areas of

the environmental sciences tailored in such a way that they will help the EPA set the mission standards for pollutants and other regulatory requirements necessary to carry out that agency's mission. These general objectives stated by the agency should be broad so that the laboratory Director has a reasonable amount of freedom to develop the specific program that implements the objectives.

2. The laboratory should set up the research program inside the general objectives as laid out by the agency and then tell the sponsoring agency what it plans to do in detail to help the agency's mission. The laboratory should write a program plan each year saying what work will be carried out during the following year for the agency. This is a control document. The agency should approve the plan if it is appropriate. The agency should not try to micro-manage the program.

3. The agency should accept the peer review by the NAS or an equivalent mechanism as the necessary oversight of the scientific program of the laboratory.

4. The agency should review the administration and management of the research laboratory once every two or three years. Inside the flexibility inherent in the system I have outlined, the agency could change the management, and alter the research program if necessary to produce first class work in appropriate areas.

This image of a research laboratory I have put forward works. I know it works because it is more or less the system we have at NCAR. There are a

few world class laboratories that operate under the Civil Service System such as the Wave Propagation Laboratory of NOAA. It is frankly surprising to me this is possible at all. I am convinced by experience that it is much easier to do high quality work inside the system I have described.

If the government really wants to do first class research in its mission agency laboratories, it has to change the rules and operate with a system that has much more flexibility and much more motivation built into it. I know it is possible to develop world class laboratories when you operate with these flexibilities. I believe it would be next to impossible to start a research laboratory now inside the current regulatory constraints on government laboratories and ever develop a world class organization.

Thank you for the opportunity to appear before the Science Policy Task Force. I would be delighted to answer any questions you may have for me.

Mr. FUQUA. Thank you very much, Dr. Hess.

I am going to have to excuse myself in a few minutes. We have a conference committee meeting this morning on an item called Gramm-Rudman that might have some impact on both of you.

I would like to address this to both of you. Getting back to the Packard Commission recommendation on the scientific personnel system—and I have introduced a bill to accomplish that—as an alternative to that, if we cannot get that bill through, would it be bad to convert all the Federal labs over to GOCO's? The two that you two come from do rather well as a GOCO—Government-owned, contractor operated. Would that be the worst thing in the world?

Dr. HESS. I think there are some things that would be practical problems with it. I am not sure that it is the worst thing in the world, but I would submit that if you took a laboratory that had been in existence a long period of time as a civil service laboratory and tried in a short time to convert it to a privately operated laboratory, you would present some problems for some of the employees in the lab who might have 18 years of civil service and are working up toward retirement. If you suddenly take them away from that system, you cause them a practical problem.

I don't think there is any particular reason why any one particular laboratory should not be converted to a privately operated laboratory if there is a gradual and reasonably long transition period. I would submit it is probably not proper to try to do all of them.

Mr. FUQUA. Dr. Stark?

Dr. STARK. Aside from the issue of the retirement issues, my personal feeling is that the GOCO—Government-owned, contractor-operated, laboratories—certainly have the degree of independence and decentralization of authority and responsibility that I personally feel makes for a much stronger institution than is possible with many of the federally operated laboratories.

Mr. FUQUA. What discretionary funds do you have in the Los Alamos or the members of your group and also NCAR, as we discussed with Dr. Packard, that you can do independent research with your scientists?

Dr. STARK. Within Los Alamos, we have a program called institutional supporting research that is considered a part of the laboratory's budget. It is part of the laboratory overhead item. An internal committee decides on a year-to-year basis which projects proposed by individuals within the laboratory to support under that program. So, it is not so much a matter of giving individuals 5 or 10 percent of the time to do their own thing, but rather a matter of making it available to all to propose to spend 6 months or 1 year or more full-time doing their own thing if they can pass an internal peer review process.

Dr. HESS. A relatively small portion of our research money is flexible, but I think the answer to the question is more or less the same answer here.

Inside our research program, our scientists are allowed a reasonable degree of flexibility. We like to see scientists working on large programs, developing a big new instrument, helping carry out a large field program, developing a big code for a supercomputer.

Also, we want that individual to be doing some research on his own.

I would submit that 10 percent is probably not enough. I think 25 percent is a more reasonable kind of a number. In our laboratory, that spectrum goes from 100 percent, in some cases, down to a small number, maybe as low as 10 or 20 percent.

When we look to promote a scientist, we look at what he has done in field programs, in developing instruments, and in writing scientific papers. We go out and ask for peer review from his peers in universities to write letters and say how well this individual has performed. If he hasn't written some scientific papers, he has some problem getting that review accomplished well.

You have to have a mix in order to evaluate the individual well and also to keep the individual motivated.

Mr. FUQUA. When we have external review committees that come in and they tell us after the fact whether we have been doing good science or mediocre science, and the research is rather expensive and it has been going on probably for several years, how can we guard against waste while trying to reduce needless reporting and so forth?

Dr. HESS. I suppose a certain amount of waste cannot be guarded against in this kind of a system, but I would submit that that amount of waste is small compared to the amount of waste that you may get now inside the laboratories where you don't have this kind of a system in place.

If you review, postfact, say, for the last 3 years of work, you might find that there were some things that went on in that last 3 years you didn't like, in which case you would try to change them. In the absence of reviewing, you may have something that is going on that is not very good for 10 or 20 years.

I think that the postfact review will show those problems adequately and the amount of waste is small enough that you ought to be able to tolerate that.

Dr. STARK. My only addition would be, I think, that reporting to agencies or others should be done on a no more frequent than an annual basis. I have been familiar with laboratory programs requiring bimonthly reports to Washington by individuals who basically had to spend their full time writing reports before the advent of word processing systems made it easy to do so.

That is a very serious issue, and reporting after the fact, indeed, can bring out problems and there is far more efficiency in the few problems that are corrected after a year in review than in trying to micromanage and correct on a monthly or semiannual basis.

Mr. FUQUA. Thank you.

Mr. Ritter?

Mr. RITTER. Thank you, Mr. Chairman.

You mentioned some very substantial difficulties, Dr. Hess, on the personnel side. What about the facilities and equipment side? Where do we stand today vis-a-vis the competitive research arena compared to where we stood 10 years ago?

Dr. HESS. I think universities have a serious problem in the matter of research equipment. I am not familiar in detail with this, so I would say I have heard this secondhand from many colleagues who——

Mr. RITTER [acting chairman]. I am thinking about the labs. We have heard a great deal about the university problem, but what about the labs themselves?

Dr. HESS. Inside the Federal lab system, there has been a big step forward in the last year in the matter of providing supercomputing capability to the laboratories and the scientists related to laboratories. I would submit that that is probably in pretty good shape.

Inside the laboratories I am familiar with, there are serious needs for other kinds of equipment. At least in our laboratory, that is in direct competition with salaries for scientists, and you always have to compromise on this. You end up compromising in ways where you get good scientists, you get some equipment, you end up somewhere in the middle. There are clearly needs for new equipment in Federal labs.

Dr. STARK. I think I would say the needs for Federal laboratories are far less pressing or acute than the needs of universities in this area.

Mr. RITTER. The chairman mentioned trying to solve some of these personnel difficulties via the GOCO route. Is there a need for perhaps a legislative approach which would address not only the personnel difficulties but the idea of defining mission? Are we at a stage where the system has somewhat not kept up with the needs of the times in that there are such constraints on the national and Federal lab system that they are almost hamstrung to respond?

Dr. STARK. I don't know if there are any restrictions that are there intentionally, but I think the system has evolved in such a way that we are to some extent hamstrung. If we ask the question who is responsible for long-range strategic planning as to the types of research that ought to be carried out in the Federal laboratories, I would be hard pressed to find examples of where that is done very effectively from the standpoint that it is made very clear to the laboratories well in advance where they should be going.

That is a clear issue to me.

Mr. RITTER. Dr. Hess?

Dr. HESS. We are not a Federal laboratory in the normal definition of that phrase in Washington, and we are not hamstrung in that sense. We have a quite clearly defined mission which is to help universities carry out basic research. We work closely with the National Science Foundation which is our sponsoring agency in setting up programs to accomplish that, and we are very closely reviewed by university groups.

I don't think we have a problem with the mission or how we carry out the mission. I think we are reviewed and counseled at about the proper level. I can't answer for other Government labs.

Mr. RITTER. So, there seems to be some differences. The NSF-run laboratories, would you say, have better definition and less hamstringing?

Dr. HESS. In our case, that certainly is true. I don't know that I should generalize that, because I don't know enough about the other laboratories to say that.

Mr. RITTER. What about the Dole-Michael-Ritter-Shaw-Fuqua bill for some financial incentives within the system to participate in royalty sharing? Dr. Stark, could you comment first?

Dr. STARK. I am well familiar with that initiative and I personally support that very strongly from both standpoints that, No. 1, it provides a real opening for patents or other technology developed in the Federal laboratories to become pragmatically available to American industry where pragmatic availability may include the need for exclusive licensing which is otherwise difficult to obtain. From the standpoint of royalty sharing, my one concern would be that royalty or other income flowing back to a laboratory be made available to reward not only commercial innovation but also important mission related innovation and contributions by members of the technical staff.

Dr. HESS. I think the concept of royalty sharing is a very good one and should be pursued. I don't think practically for my laboratory it will amount to very much, because we do not get into situations which lead to the development of new systems where you are likely to make very much money.

Mr. RITTER. Gentlemen, thank you very much for your excellent testimony.

[Answers to questions asked of Dr. Stark and Dr. Hess follow:]

Federal Laboratory Consortium

November 22, 1985
ADIII-85-1126
P373
505/667-4960

RECEIVED
DEC 2 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

The Honorable
Don Fuqua
Committee on Science and Technology
2321 Rayburn House Office Bldg.
U.S. House of Representatives
Washington, DC 20515

Dear Representative Fuqua:

This is in response to your letter of October 24 requesting that I address specific questions for the record of the October 22 hearing of the Task Force on Science Policy. These responses reflect my personal thoughts on these subjects as garnered from interactions with individuals from a wide spectrum of federal laboratories through my role as chairman of the the Federal Laboratory Consortium (FLC). Several generalizations may not be applicable to all laboratories or agencies.

1. The costs of technology transfer and the laboratories' enthusiasm.

In most agencies, technology transfer is mandated as an overhead function of the larger laboratories. This approach has ensured that costs are minimal; thus the highest-value transfer opportunities are emphasized. The benefit-to-cost ratio is therefore high.

Positive attention was not generally given to government-industry cooperation and technology transfer in the 1970s. However, the passage of the Stevenson-Wydler Act in 1980, the continued congressional interest in its implementation, and more recent emphasis on international competitiveness of US industry have created a strong climate to which the laboratories are responding. Significant strengthening of technology transfer has been evident in the last four years and indications are this trend will continue.

2. Allocation of transfer resources.

The NASA Technology Utilization program has had the most resources available. There has been a smaller allocation of technology transfer resources at other federal laboratories. All such resources, including NASA's, sometime find the demand and opportunity for transfer outstripping available resources. On a laboratory-specific basis, consideration is given to increasing resource allocations based upon detailed analysis of incremental benefit and cost, applied with particular stringency in laboratories that support this activity from their overhead activities.

FLC CHAIRMAN
Los Alamos National Laboratory • MS F-685 • Los Alamos, NM 87545 • DR. EUGENE STARK • (505) 667-4960

The Honorable Don Fugua November 22, 1985

3. Laboratory functions and contribution to national goals.

The laboratories have few major functions that are not an integral part of their assigned missions. Some important functions within the missions include the maintenance and improvement of facilities, equipment, expertise, and technical vitality of the staff. Other functions are mandated by the government or are a consequence of their mission activities; these include use of unique capabilities to address other federal needs, the professional-society contributions by the staff, contributions to the educational system, and technology transfer.

Some laboratories strive to address "national goals," however, their mission activities must have first priority. Functions related to technolgy transfer and education may contribute, for example, to the generally-understood national needs in these areas.

The above observations are consistent with a trend by the laboratories toward an increased focus on their assigned missions.

4. Quality of Technical Personnel.

Until recent years, the federal laboratories had an excellent record of attracting and retaining high-quality technical talent, at least from the staff levels through middle management. The increasing difficulties of government-operated laboratories can be traced largely to salary differences with the private sector - an issue that has become critical.

5. Policy on Laboratory Establishment and Reorientation.

This policy area has not been a subject of discussions, either formal or informal, within the FLC. These are issues that must be considered carefully by each agency in its responsibility for stewardship of these major facilities and the substantial institutional expertise they maintain.

6. Roles of laboratories relative to universities and industry.

There is minimal duplication of work between the laboratories and other sources of R&D. The ultimate goal of each laboratory program requires a certain level of continuous in-house development that must be fed by applied research, which is often dependent on basic research. These requirements for continuity, independence, government-validated results, and goal-centered activity characterize the laboratories' roles.

An important step in strengthening American science and its results is the present trend toward institutional cooperation to mutual advantage. For example, the laboratories may offer greater educational and research opportunities for the universities, using government-owned facilities and equipment; program and research collaboration among these three sectors can strengthen their mutual respect and understanding, leading to strengthening of all the institutions and a better net return to society.

Sincerely,

Eugene Stark
FLC Chairman

ES:rc

Cy: CRM-4/A150 (2)
File

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
P.O. Box 3000 • Boulder, Colorado 80307-3000
Telephone: (303) 497-1000 • Telex: 45 694 • FTS: 320-1000

RECEIVED
NOV 19 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

15 November 1985

Mr. Don Fuqua, Chairman
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Fuqua:

Enclosed are my responses to the Questions for the Record which the Members of the Task Force submitted.

If you need any additional information, please let me know.

Sincerely,

WNHess

Wilmot N. Hess
Director

Enclosures

The National Center for Atmospheric Research is operated by the University Corporation for Atmospheric Research under sponsorship of the National Science Foundation
An Equal Opportunity/Affirmative Action Employer

WNHess/11/11/85

RESPONSES TO QUESTIONS RE HESS TESTIMONY

1. What is the role of the National Science Foundation laboratories versus mission agency and private sector labs?

The NSF national laboratories were established to be extensions of university research capabilities, in order to advance the progress and the usefulness of university-based research and education. They carry out or assist programs primarily in basic research.

It has long been recognized that a strong economy and our national security depend on a strong infrastructure of basic research, and that the universities represent the deepest reservoir of talent in basic research. Futhermore, there is a very close tie between university-based research and the training of the next generation of basic scientists.

The purposes of mission agency and private sector laboratories are different. Mission agency labs are there to help the agency improve and modernize the performance of the agency's mission. Laboratories of private companies are directed toward the short or long-term profitability of the company.

There is frequently some healthy overlap between the work of NCAR scientists and their university collaborators and that of scientists in mission-agency laboratories, and sometimes there are joint projects shared by NCAR, universities, and the mission agencies. These activities promote progress in basic research and they help to move basic knowledge into use by the mission agencies.

2. What, besides the primary mission, are NCAR's functions? How are national goals as well as agency missions served?

NCAR has a dual mission:

- To plan and carry out research programs of highest quality on selected problems of national and international importance and scope.

- To identify, develop and make accessible selected research services and facilities of the outstanding quality required by the universities and NCAR for effective progress in atmospheric research.

NCAR's mission thus differs from the other NSF laboratories, which specialize only in providing powerful research tools, such as large telescopes, to the astronomical research community. In contrast, NCAR's mission is to work in concert with universities to bring about collaborative research programs that a single university cannot tackle alone. This means not only the provision of facilities but also scientific leadership in the identification, planning and execution of research activities of importance to the nation.

NCAR's facilities are so large, expensive, or complex that they could not easily be acquired or developed by a single university. We now have two CRAY-1 computers that are provided to NCAR and university researchers. This coming summer we will get a new CRAY X-MP 4800 computer to augment our computing capabilities for university work. Our computers presently serve roughly 1000 university users. We have four specially instrumented research aircraft that carry out research on severe storms, atmospheric chemistry, and studies of the surface of the ocean. We also have probably the world's best Doppler radar.

Our four aircraft, three Doppler radars, sixty automated meteorological ground stations and other specialized equipment are used nearly every year in large field experiments. We frequently take lead responsibility in organizing and managing field experiments and in preparing the data for use by investigators afterwards.

Another function of NCAR is education. Every summer we have one or more short courses for graduate students and young PhD's from universities in such subjects as atmospheric chemistry, advanced instrumentation, and how to use a CRAY computer. We have about twenty-five post doctoral fellows in residence at NCAR at all times. Each year, we have about twelve graduate students, jointly sponsored by NCAR and a university, working on thesis problems. We have roughly forty other long-term visitors (six months or more) carrying out special projects with our staff. A large reason for the existence of our research staff is to work jointly with university scientists.

In carrying out our NCAR research, we frequently get involved in national problems because we have capabilities which can be brought to bear on them. We are presently working on the development of an acid rain model for EPA. This is to be delivered to them next year. It will clearly be the best meteorological-chemical model that has ever been built anywhere. Specifically it will help to do the job of understanding and regulating the formation of acid rain.

We have worked for several years on problems of aviation safety, especially the phenomenon called downbursts. This down-flowing of cold air out of a cumulus cloud can pose a serious hazard to an aircraft when landing or taking off, as was recently learned in the Dallas airport

tragedy. We have studied the characteristics of downbursts, their occurrence, duration, and severity at the Denver Stapleton Airport. We are getting ready to do this at other sites and also to work with FAA on the development of a Doppler radar system to warn aircraft of the occurrence of downbursts.

We have worked on the problem of nuclear winter. Our Community Climate Model was the first one used to study in three dimensions the climatic effects of the soot cloud that could result from a nuclear war.

We work on national problems when we consider we have a special capability that can be brought to bear, and where we feel it is an appropri te extension of our overall program.

3. To what extent do Federal laboratories conduct research in-house that could just as well be performed at a university or a private research institution? How can we ensure that the Federal labs do not usurp the roles of these other institutions?

Laboratories of the mission agencies have special kinds of research programs to help improve the agency in the conduct of its mission. For example, the NOAA Environmental Research Laboratories developed Doppler radars which are now ready to be put into operation by the National Weather Service in their NEXRAD program. This kind of research which takes a decade or more and many people to carry it out is not appropriate for a university. However, there are research functions in mission agency laboratories that can be carried out by universities. An example of this is the pre-STORM program carried out last spring by NOAA-ERL, NCAR and about twelve universities. This joint project collected new data on how severe storms work, and is a good example of cooperation by the mission agencies and university researchers.

In certain other federal laboratories where the mission of the organization might not be as well defined (the Packard Report suggested some of the DOE laboratories might have this problem), there may be more confusion about the role of the laboratory and the role of university research. I cannot speak with firsthand knowledge about these situations.

It would be possible to lessen the likelihood that federal laboratories do not usurp the roles of universities by using the scheme I put forward in my testimony. A committee of the National Academy of Sciences would be formed to advise a mission agency on whether its research laboratories of the agency were doing appropriate work, or whether it was more appropriate to be done at a university. If so, then the agency directors should see that the laboratory moves that work outside.

4. Please describe the process, timing, and support necessary to convert a government-owned, government-operated laboratory from the civil service system to a personnel system similar to the one used by NCAR.

I do not have a well thought-out scheme for converting a GOGO laboratory to the personnel system used at NCAR. There are two different ways this could take place. The laboratory could become a contractor-operated laboratory, or the laboratory could stay in civil service but have a very different personnel system such as the Navy China Lake Lab has used in recent years.

In either case you want this process to proceed rather slowly because you are trying to improve the quality of work carried out and attract better scientists to the program. You need to protect the productive scientists who have been in the laboratory prior to this period. If a person has eighteen years in the civil service system, he almost certainly wants to continue working for two more years to get twenty years service, in order to achieve a certain retirement status. He would not want to be told suddenly to transfer to a new system with different retirement arrangements. I would suggest that probably a period between five and ten years be allowed to carry out the complete transfer. New employees brought into the laboratory should come in under the new personnel system. Old employees should have the privilege of retaining the present personnel status or transferring to the new personnel system.

There is a danger in having the new personnel system be inside a GOGO laboratory. If this personnel system is administered by the Office of Personnel Management in Washington, it may fail, as the Senior Executive Service has failed. A personnel system has to be allowed to function as designed. If OPM were to put artificial restrictions on top salaries or total amount of money that could be paid, or total number of personnel in the system, you will eventually arrive at another failed system, like the SES. Safeguards have to be built into the system to prevent this. I feel it would be better if the new personnel system in a GOGO was administered by the agency with only very general, broad overview from OPM.

Mr. RITTER. Our fourth witness is Dr. Franklin A. Long, former professor of chemistry at Cornell University and cofounder of Cornell's well-known Program on Science, Technology, and Society. Dr. Long will discuss the prospects and problems of Department of Defense support of research in U.S. universities.

Dr. Long, welcome to our Science Policy Task Force. We look forward to your testimony.

STATEMENT OF DR. FRANKLIN A. LONG, PROGRAM ON SCIENCE, TECHNOLOGY, AND SOCIETY, CORNELL UNIVERSITY, ITHACA, NY

Dr. LONG. Let me first say that it is really a very great pleasure and indeed an honor to be able to appear before this committee. It is an important committee, and you have done a good job. If by the kinds of things we say at meetings like this we can help you do a better job, we will all be happy.

What I want to talk about is something in general about Federal support of research and development in universities and then quite specifically relations between the universities and the Department of Defense which is, after all, the largest funder of our R&D in the Federal Government and deserves a little special attention.

As you have gathered and as you have implied, I spent a good many years of my life as an academic scientist in chemistry. My academic life has been very heavily at Cornell. However, I have been involved substantially in military activities. I spent 3½ years in a war laboratory during World War II and was a consultant and member of boards on a number of military activities. I was a member of PSAC for several years, and one of my assignments was to chair the Committee on Strategic Weapons.

So, my concern with and interest in the military is long standing. On the other side of the coin, I did spend 2 years as Assistant Director of the U.S. Arms Control and Disarmament Agency which is a different kind of view of the world. Finally, I spent several years as vice president of research and advanced studies at Cornell which gave me a kind of general feeling of the problems and opportunities for research in universities. It is from this background that I will be talking.

I won't follow my paper very closely and will try to condense materials. Let me start by commenting on the very obvious importance of the Department of Defense as a supporter of R&D. It is now getting to the point where it is spending about $40 billion a year on R&D, and that constitutes roughly two-thirds of all of the Federal funds that go into R&D, so it is a very substantial and very important agency.

All of this started dramatically, it seems to me, at the end of World War II. Before World War II, the military spent remarkably little on R&D. Their own budgets were pretty small, but even for those small budgets back in 1939, the military percentage of the total military budget that went into R&D was only 0.6 percent, a very modest amount indeed. What happened was that the clear importance of science-based technology during World War II caused a rethink, and DOD very promptly moved after the war to support research. Now, of course, not only is the budget $40 billion a year,

but that represents 12 percent of a very much larger total support for the DOD's programs. So, the evidence that R&D is important to the military is certainly very clear indeed.

One thing I do want to emphasize at the start is the degree to which DOD was a real pioneer in some of this. It established very quickly after the war the Office of Naval Research, and I think that was a truly and important agency. From the start, it agreed to support research at universities and did. It very quickly decided that it would respond to proposals sent into it from faculty by way of their university offices, so it was responding to the interests and desires of research people in universities. Then, it developed very quickly a peer review system for evaluating these. Both of these approaches have turned out to be very important and widely used through the years ever since.

For a little while, DOD was the major supporter of research in universities. That changed pretty rapidly, partly because other mission-oriented agencies like Health and Human Services and Agriculture and NASA and Energy—AEC in those days—began to support lots of research, and NSF came in very quickly. So, over the years, the importance of DOD as a supporter of research in universities has diminished but is still pretty significant.

This large Federal commitment to support research in universities, I think, has been a very great consequence, certainly to the universities and, I think, to the country. The agencies have effectively—and remember that the majority of these agencies that support research in universities are mission oriented. In spite of that, they have turned extensively to the universities for basic research and for long-range applied research, particularly in science and engineering but not limited to that.

Of course, from the point of view of the universities, there has been a very important synergism between their work and the work and desires of the mission-oriented agencies in that the research is a crucially central element of teaching in universities, particularly at the graduate student level, and so that this enhanced support for research strengthened a great deal the teaching capabilities of universities, and I would like to think that the research they produced was useful to the agencies themselves.

Someone used the phrase "research university" and that is exactly what was developed in this country—these large, vigorous universities in which research plays a really central role. It is clearly important still in teaching, but I think it is fair to say that the level and characteristics of university research has gone somewhat beyond even just the teaching responsibility.

A very substantial effort indeed, but what has the country got out of this large expenditure for research in universities? In the first place, they have clearly got large numbers of well-trained graduates and postgraduates. Scientists and engineers are one of the groups that we tend to think of, but in fact the development of a quality activity has permeated the whole university.

Another thing that this substantial funding of research has permitted universities to do is to move remarkably quickly into new fields of research. They really have been quick to pick up new ideas and to develop them and to make substantial efforts in them. The way they moved very quickly into computer research is one illus-

tration. The way they moved very quickly into genetic manipulation and now into biotechnology is another.

So, I think the country has something for this money that has been plowed in from the Federal agencies into the universities.

As a statistic, the universities of the country produce now about 70 percent of all of the publications in basic research that come out of the United States. They produce, and this is I think a more remarkable statistic, 55 to 60 percent of all of the publications in applied research. So, they really do make a large contribution, and by the kinds of criteria that you can use to measure the quality of research, it is quite clear that the product is a quality product. It is good research that they are doing.

In the paper, I included a slide which showed something about who were the major supporters from the Federal agencies for universities. It turns out that the major one is Health, Education, and Welfare with NSF a somewhat poor second and the Department of Defense a very close third. These are the two largest support agencies from the Federal Government. Note that two of them, at least, Health and Human Services and Department of Defense, are mission-oriented and so are the other significant ones, Agriculture, Energy, NASA, all have that character.

The figures for DOD in table 1 of the paper are somewhat interesting because DOD, which is third in support, is spending just a little less than $1 billion a year for fiscal 1985—as estimated but pretty close to correct. They are, interestingly, leader in the support of development in universities. In the main, what universities do is basic research and applied research. About, crudely, 65 percent, two-thirds, roughly, of their effort is in basic research. About 25 percent is in applied research, and the rest in development. Of that modest development component, DOD supplies something more than half of the development money, consistent, I think, with the picture we have of DOD as very much an applied agency interested in products.

The other table which was of some interest which is not in the paper—and I will give you just a few figures—DOD's total Federal expenditures—if you compare 1980 to 1985—total Federal expenditures have gone up in current dollars by something like 60 percent. During that period when total Federal dollars have gone up, the amount into universities and colleges has dropped. It dropped from in 1980, 37 percent to in 1985, 31 percent. And at least part of that goes directly with the fact that it was the DOD budgets that went up with particular rapidity during this period.

Another statistic is that during this period, the funds to universities from Federal agencies increased but only by a very modest rate of increase. Over the 5 years in constant dollars, the figures to universities went up only 7 percent. So, it is fairly close to constant over those 5 years.

Now, relations between these agencies, including the mission oriented agencies, have on the whole been remarkably good. Because of the synergism, the fact that they do have quite fundamentally different missions has not prevented them from working pretty well together, I think, in the main.

I am going to turn and talk about tensions between DOD and the universities, but it must be seen in context of overall, among all of the agencies, pretty good working relations between the two.

The role of the DOD in university programs is, as I noted, fairly modest. Only 2.5 percent of their total budget, which is now getting to be $40 billion, goes into universities. As a fraction of what the Federal agencies do, they do about 15 percent of their total support. So, they are an important agency for support of universities but not a dominant one.

It is true that in recent years, especially the last five, perhaps, tensions between DOD and the universities have increased quite a bit. I do want to talk about those. I will be talking about them from the point of view of the universities. If you had a DOD man sitting here, he would have another set of things to say about these tensions, but you will hear the university story.

It seems to me that there are five principal reasons why tensions have built up between DOD and the universities. The first one is DOD pressure to restrict dissemination of unclassified university research on the argument that it is, in their view, sensitive—sensitive in the sense that they would feel not very happy if the results of this admittedly unclassified research got into the hands of the Soviet Union and its allies.

The restrictions have shown up in about three different ways. One of them is the desire to restrict publication of some of these papers or to postpone it for a while. The second is the desire to cut down on the presentation of some of these papers at meetings of scientists which are pretty common. And the third is restrictions on the access of foreign scientists, particularly from the Soviet Union and the Warsaw Pact nations, to visit American universities. This has shown up not only in these explicit restrictions, but it is a fact that of all the agencies, the sort of pressures on the universities to modify their normal positions of open publication and independence of their publications is probably harder from DOD than I think any other agency, although the DOE, perhaps because of its own coupling to military programs, is also somewhat involved.

The second thing that leads to tensions has been, at least in recent times, a general push from DOD for getting more goal-oriented research out of the universities. The DOD sends in quite a lot of what are called requests for proposals, and many of them deal with pretty applied subjects. The particular illustration that has been in the news recently is the DOD interest in getting more work on the Strategic Defense Initiative, the star wars research program which is underway.

A third area for tension—and this is showing the universities' self-interest—it is that the universities are concerned that the very substantial buildup of funds for research in DOD and the tightening-up of funds for research of the more civilian-oriented agencies worries the universities that their trouble in getting support will increase as the fraction of the total Federal support goes up. There is a table in my paper that goes into that, and I won't go into details except to give you the total summary. It is for the 5 years between 1980 and 1985 again, and the important single figure is that the funds that have gone into the area of R&D for national defense

have gone up in those 5 years in constant dollars by 74 percent, a very handsome increase indeed. The funding for all other elements of the Federal support, all the other agencies, most all of which are civilian oriented, has in the same period gone down 17 percent. It is that difference in the direction of increased support which is worrisome to the universities.

I might note that the proposal that the "Star Wars" R&D program will grow very rapidly up to amounts like $6 or $8 billion a year in the next 2 or 3 years is part of that general worry that the universities may find it harder to get money for their fundamentally civilian-oriented programs.

There are two other reasons why universities are troubled by relations with DOD which are more political, I think it is fair to say. One of them is a concern among many people in universities about the approaches of the Department of Defense to their goals, and also the very strong emphasis on a military buildup, apparently very little interest in arms control or negotiations or alternative ways to search for national security, and a fairly aggressive stance against the U.S.S.R., including for the recent years at least a comparative neglect of arms control possibilities.

So, there is a sense of just doubt about the priorities which the DOD has. Now, as I am sure, the DOD, if it were here, would reject that and say that on the contrary they are entirely consonant with the best definition of national security, but a good many people in universities worry.

The fifth one is pretty much an internal matter, namely, that the universities, many people in universities, are worried about the balance of effort within their own institutions. Aren't they putting in too much money working on military related programs, even if it is long-range research, as compared to working on other ways for national security, arms control, unilateral moves—a dozen things that one might think of? That was a feeling, by the way, that was very high in the sixties in universities. It declined very much in the seventies, and now I think it is beginning to increase again.

So, these concerns are not trivial and they do influence relations. I do think, though, that you ought to put them in perspective in the following sense, that the average, typical university scientist who has a contract from the DOD in the main is quite pleased with it. That is to say, the negotiations from his point of view—not necessarily from the university's, I might say—but from his point of view are clear and there is a sense that DOD is interested in quality and once they have a research project, it goes along pretty well. So, the DOD is, I think, enlightened in many of its approaches to universities.

What is going to happen in the future? Well, in the first place, this kind of tension that I have mentioned could, of course, disappear or at least decrease quite considerably with certain modest changes. If, for example, the Reagan-Gorbachev Summit goes well and if the Soviet Union and the United States do enter into serious negotiations, I am sure that would make a great deal of difference in the feelings of many people. The new administration which will be coming along in a few years might not be so aggressively negative about arms control and disarmament possibilities.

Still, one has to come back to where DOD is in this total picture and where is it in the support of university programs. My own feeling is that if DOD is going to stay the dominant picture in Federal support of R&D and, in fact, if its fraction of moneys from the Federal are going to increase, as looks pretty likely given programs like SDI, I think this committee and, I hope, the DOD ought to think pretty seriously as to whether it should not actively be involved in giving more support to long-range research and to basic research in the universities—partly for its own interest and partly for the national interest.

Any university scientist if you asked that would say, "Gee, wouldn't it be nice if that could be done by NSF which we know and understand and which has this direct mission"—but that is probably unrealistic in these days of tight budgets. So, I would like to at least put a proposal on the table; namely, that there try to be a situation developed in which the universities do in fact have programs of support of basic and long research in universities for their general good and for the general good of the Nation, not because it tightly couples into any one goal or project of another.

It is the kind of thing that ONR did beautifully in the very early days of DOD, and I think a return to that kind of philosophy would be a very good thing. I would like to see, for example, explicit budgets among the armed services to support basic and long-range research and with moneys isolated to be used for that purpose so that it wasn't in competition with the goal-oriented programs. I would like to see the procedures that these units would use look very much like the ONR procedures of responding to initiatives, requests for support from university scientists and other scientists, utilizing peer review to examine quality and making awards on the basis of peer review, and to be happy, in fact, desirous, that the research be coupled with the teaching activity so that it is coupled into training of Ph.D's and postdoctorates.

I am heartened in thinking this is not a foolish thing to propose by a remark from a very longtime worker in the DOD for the DOD by the name of Al Flax who was once Assistant Secretary for the Air Force and has had many responsible positions. He wrote a paper for a book we did a few years ago, and he was contrasting the situation in the United States and the Soviet Union and said that his own strong belief as to why the United States was technically clearly superior to the Soviet Union in almost all aspects of military technology was that the United States was building on a much stronger civilian base of science and engineering. It is that that I think is the logical reason why the DOD might give some much more explicit support to that.

I could go on and talk about how much and a little bit in details, but I think I have said enough. I think it is important, incidentally, that DOD and the universities do work together. They have for many years. I would like to think that this recent buildup of tensions is a short-term thing and will minimize in the coming years, but it would be wrong not to call your attention to them at this point.

Thank you.

[The prepared statement of Dr. Long follows:]

Prepared for House Committee on Science & Technology

10/18/85

DoD Support of Research in US Universities:
Prospects and Problems

F.A. Long
Cornell University

The Department of Defense has much the largest program of research and development (R&D) of the US federal agencies, and its program has been growing rapidly in recent years. Historically, DoD has been involved in supporting R&D in universities since soon after World War II. Other federal agencies have followed DoD's lead, and support of university research by these agencies has been a major factor in the growth of scientific research in the US.

Even though among the federal agencies DoD no longer ranks as the largest supporter of university research, its interactions with universities, particularly with respect to restrictions on dissemination of research results, have been of special importance. This paper reviews the current status and future directions of these interactions from the point of view of the universities.

The development of interest by the US military in science-based research and development was dramatic. In the years before 1939 only a few million dollars of the military budgets went into research. In 1939 only 0.6% of US military budgets was allotted to R&D. The very large impact of science-based research on new weapons and new military materiel during World War II changed all that. Today US funding for research and development for the military amounts to about $40 billion per year, and constitutes roughly 12% of the total US budget for military activities. Since the US Department of Defense is clearly and emphatically a mission-oriented agency, one can firmly conclude that DoD sees research and development as a major component of the fulfillment of its mission.

DoD is not alone in recognizing the importance of research and development. The same applies to most of the other mission-oriented federal agencies: Health and Human Services, the Department of Energy, Agriculture and several others all see R&D as an essential element for their programs.

What is remarkable, however, is that these mission-oriented agencies have all seen the US universities as an important source for generating some of the research that they needed. As a consequence, the build-up of support of university research by mission-oriented federal agencies has been impressively large. Pre-1939, federal funds for research in US universities was negligible. Now federal funds constitute roughly two-thirds of the total support for research in US universities, and the majority of this support comes from mission-oriented federal agencies. The US military services were among the first to appreciate the contributions the university research might make to their missions, and the first substantial, and indeed continuing, program of federal support for university research was the Office of Naval Research (ONR) established just after World War II, with a major commitment to support to scientific research in universities.

ONR was a true pioneer. Not only was it the first federal agency to allot substantial funding for research in universities, it also established the procedures of permitting university scientists to submit individual proposals through their universities for support of their research, and then established a peer review mechanism to evaluate such proposals. These particular procedures are now deeply ingrained in the federal support system for US universities. I was involved in the ONR program for chemistry in the post-war years, and similarly involved in the program for the soon-established Air Force group called the Air Force Office of Scientific Research, and I can testify of the deep commitment of these groups to support first-

class research and of their complete willingness to utilize peer review in evaluating proposals. These were the trail-blazers for the NSF and other federal agencies.

For a few years after World War II support from the military services dominated federal support for university research, but this soon changed. Rapid build-up of research programs in the Atomic Energy Commission, in the National Institutes of Health, and in the new and important National Science Foundation, soon left the DoD in the position of being only a modest component of federal support of university research.

This willingness of mission-oriented federal agencies, as well as NSF, to support university research was invaluable to US universities, and their support played a major role in the rapid blossoming of what we now call the research universities of the US, those big, vigorous academic institutions where research plays a central role. Given that the missions of the universities and the agencies are quite different, it was probably inevitable that some tensions would build up between them, and they have, but it is remarkable that the tensions have in the main been fairly minor and sporadic. Both parties have, I believe, clearly benefited.

The primary function of research in universities has always been and remains to contribute to teaching. This applies especially to training of post-graduate students, where independent research by students constitutes a major component of their programs towards a Masters or Ph.D. degree. Because universities are the places where these advanced degrees are principally given, it is not surprising that the universities are overwhelmingly dominant in the production of research in US institutions of higher education.

An important element in relations between universities and research-supporting federal agencies is that overall the federal funding of research

has never covered the full costs of the research that they fund in universities. Put another way, the contributions of the universities to their research programs have always been large, and remain so. This is a problem that we have been studying at Cornell, and we are persuaded that the financial contribution from the universities to their research programs, including the federally-sponsored, is substantially underestimated. It is entirely proper that universities support research when it plays a significant role in their teaching programs. However, as university research programs expand to include the activities of large numbers of post-doctors, and more recently of substantial numbers of full-time research associates, and when new buildings must be put up to house the expanded research programs, then extensive university contributions to research costs become more and more of a burden, and less and less appropriate. For this reason alone, it is inappropriate for a university to become a "job shop" for research for outside groups, whether they be federal agencies or industrial concerns.

A closely related comment is that universities do, and in my judgement should, restrict themselves to research programs which are either for basic research or for long-range applied research. The central reason for research at universities is its coupling with advanced training of students, and the teaching process is by its very nature one in which deadlines and time-urgent demands such as are characteristic of development programs do not fit well. Equally important is that the teaching process demands open, uninhibited communication. Students and teachers must talk freely to each other, and cannot be bound by a hidden agenda or restrictions imposed from outside. University scholars also are routinely expected to communicate research results to the world by publication in the open literature. Consistent with these university objectives, the very large majority

of US universities have explicit provision against permitting any classified research on the university campus.

Within the restricted research activities that are appropriate to universities they have, however, become very important to the overall US R&D effort, and substantial support from federal agencies has been essential in universities attaining their current significance and stature. As it now stands, universities contribute roughly two-thirds of all publications from the US on basic research, and also contribute well over half of the nation's publications in applied research. The applied fields where university contributions are particularly important are clinical medicine, engineering, agriculture and biology.

The most important university contribution to the nation is probably the continuing output of highly-trained scientists, engineers and medical scholars, along with those from the other professional schools. The linkage between this output and that of research is close, however, since research is a major component of advanced training for graduate students and post-doctors.

Let me now turn from this general overview of relations between the federal agencies and US universities to the specific characteristics and problems that go with the relations between US universities and the Department of Defense. Among the operating agencies of the US government, the Department of Defense is pretty special. Its mandate, to maintain the military defense of the nation, is both deeply important and very visible. Its annual budget of roughly $300 billion is much the largest of the federal operating agencies. It has about three million employees, two million in the armed forces and one million civilians. Its procurement program of about $100 billion a year is comparably large. It purchases an immense spectrum of materials, ranging from aircraft carriers to army boots.

The DoD's program of research and development is dominant among federal agencies. It is now spending about $40 billion a year on R&D, and this constitutes about two-thirds of all federal expenditures for R&D. DoD itself spends about $10 billion per year for R&D and R&D management. Of the remaining $30 billion, the large majority goes to the companies within the US private industrial sector that work on R&D contracts from the military. The reason for this large program of commercial R&D is that the military's prime objective is to develop weapons and other products for its military forces, and the R&D by the private sector industry is usually an initial stage of projects that will ultimately lead to production of military hardware.

Relative to its large R&D budget, the amount of DoD-funded R&D in universities is comparatively small, under 3% of the total. DoD ranks only third among federal agencies in support of university research, being surpassed by the Department of Health and Human Services and by NSF. However as might be expected given its own rapidly growing budget, the contributions of DoD to university R&D have been increasing. In recent years DoD funds to universities for R&D have more than doubled, from $457 million in FY 1980 to $930 in FY 1985. In only a year or two DoD will have passed NSF to become the second-largest supporter of university R&D. In one category, support of university projects for development, DoD is already in first place. This comparatively large emphasis on development, is consistent with DoD's mission. Table 1 summarizes for FY 1985 the funding for research and development in universities of the six largest federal support agencies for university R&D.

Table 1

Funds for R&D in Universities in FY 1985 (est)
from Major Federal Support Agencies ($ in millions)
Data from NSF Report 84-336

Major Support Agencies	Basic Research	Applied Research	Develop-ment	Total
Dept. of Agriculture	150	149	2	301
Dept. of Defense	453	130	349	932
Dept. of Energy	197	112	18	327
Dept. of Health, Education and Welfare	1853	774	160	2787
NASA	174	37	25	236
National Science Foundation	976	56	0	1032
Total Funding from All Agencies	3834	1489	635	5958

The university faculty members that have received support from DoD have usually sought it and have welcomed it when it has come. Overall, however, there is considerable unease in universities about the increasing role that DoD is playing in university support, and a significant level of tension has arisen. There are several reasons, among which the following are probably the most significant:

- Pressures from DoD for increased classification of the results of university R&D that in DoD judgement are "sensitive"; along with this have come frequent calls for restrictions on presentation of research results at scientific meetings and restrictions on visits of scientists from Warsaw Pact nations to university laboratories.

- DoD desires for more goal-oriented research and development from universities; an example the recent DoD push for more R&D projects in universities for the Strategic Defense Initiative.

- Concern in the universities that the rapidly increasing federal funding of R&D for defense will lead to decreases in research support for civilian-oriented R&D.

- Skepticism and even antagonism in universities about many of DoD's goals and their approaches to them; the vigorous campaign for a space-based defense system against nuclear weapons is a current example.

- University concerns about an imbalance in university programs, stemming from a relative emphasis on military-related R&D as compared to the amount of university effort on alternatives to military approaches toward security, e.g., to arms control and to international negotiation; this concern was particularly strong at universities during the 1960s; it declined in the 1970s, but is again on the rise.

The following sections comment briefly on each of these areas.

A large fraction of the R&D that DoD supports is classified confidential or secret, and it is not surprising that DoD would frequently wish to see classified work done on university campuses by scholars with particular knowledge and interests. However, most universities decided at the end of World War II that classified research on campuses was incompatible with the openness that should go with teaching, and have barred classified research. Recently the DoD has put more emphasis on trying to restrict the spread of certain types of unclassified, i.e., open, results of university research. The usual reason was that the results of certain university research projects seemed "sensitive" to groups within DoD, who apparently believed that US security would suffer if the results were available to the Soviet Union or its allies. This has led to restrictions on presentations of research results at meetings, and a number of attempts to keep foreign scientists away from laboratories where potentially sensitive research (in DoD's eyes) was being done. The scientific community of US universities has reacted

strongly to these attempts, one indication being the well-known Corson Report from the National Academy of Sciences. In response to considerable concerns from universities, DoD has been restrained in applying restrictions, but their desire to restrict dissemination of some research results seems unchanged, and hence this topic remains a source of substantial tension between DoD and university scientists.

Among the federal agencies that support significant amounts of university research, the Department of Defense is clearly the most goal-oriented, i.e., the most focussed on getting useful products from applied R&D programs. As one illustration, DoD expenditures for basic research are only about 2% of their total R&D expenditures, whereas the overall average of the federal agencies is over 10%. In its grants and contracts for R&D in universities, almost 40% of the DoD projects fall in the category of development, an emphasis that is not shared by the other major federal supporters of university research. Since it is the results of development projects that are the most likely to be candidates for classification and for restriction of presentation or publication, the reason for some university concern is understandable.

It is equally understandable that universities are concerned that the rapidly increasing allotment of federal R&D funds to the DoD will lead to decreases in support of civilian-oriented research, which is the area that university research has mainly emphasized. The statistics on the trends in federal funds for R&D in recent years are given in Table 2, and amply demonstrate that as research funds for national defense have increased during recent years, funds for civilian R&D programs have decreased. From 1980 through 1985 federal R&D funding for national defense increased in constant dollar amounts by 74%, while R&D funding for the other functions, almost

all oriented toward non-military activities, dropped by 17%. It seems very likely that this trend will continue, and may even grow worse as the full impact of the large new R&D program for the Strategic Defense Initiative builds up.

Table 2

Federal R&D Funding by Budget Function
(Current and Constant Dollars in Billions)
Data from NSF 85-322

	'80 act	'81 act	'82 act	'83 act	'84 act	'85 est	'86 est	% inc 80-85
Total	$29.74	33.74	36.12	38.77	44.21	50.48	58.26	
Constant $	37.82	39.01	38.98	40.22	44.21	48.68	53.99	+29
Nat'l Defense	14.95	18.41	22.07	24.94	29.29	34.33	42.36	
Constant $	19.01	21.29	23.82	25.89	29.29	33.11	39.26	+74
Nat'l Defense % of total	50	54.6	61.1	64.3	66.3	68.0	72.7	
Non-defense	14.73	15.33	14.05	13.83	14.92	16.15	15.90	
Constant $	18.73	17.73	15.16	14.36	14.92	15.57	14.73	-17
NSF deflators FY 84 = 100	.7862	.8647	.9266	.9633	100	1.037 est	1.079 est	

In addition to these widely-shared university concerns on recent directions of the new R&D program for the military, there are two somewhat more political comments. First there is considerable skepticism and occasional antagonism within the university community about some of the goals and approaches of the Department of Defense. These feelings are by no means universally shared, but they are substantial and have been growing in recent years. In many cases this skepticism and doubt about DoD goals and approaches relates to the specific objectives just discussed; however, many go beyond this and are expressed as concerns that the DoD approach to international security is imbalanced, giving undue attention to the military

side of national security and too little to the side of negotiation and arms control. In a sense this is unfair, in that one should expect a particular agency, in this case the agency for the military, to emphasize its own particular area of responsibility. However, DoD representatives from such offices as that for International Security Policy have, in the eyes of many university faculty, been all too vigorous in denigrating the utility of negotiation and arms control measures. Hence the skepticism.

A related concern questions the balance of teaching and scholarship in universities on the broad topic of national and international security. The specific concern is that universities are giving comparatively much more effort and time to studies on the military aspects of national security, and much too little to political and social aspects and non-military methods to enhance security. This train of thought developed dramatically during the student dissidence in the 1960s. It had greatly diminished in subsequent years. However, it is now increasing in universities, and represents a serious train of thought and discussion. Once again, the most dramatic illustration is the feeling about the rapidly increasing R&D program called the Strategic Defense Initiative. Very few university scientists and engineers accept the feasibility of the goal of perfect defense against nuclear weapons as enunciated by President Reagan in 1983. The many skeptics argue that the Strategic Defense Initiative will not attain its goal, will be very costly, and may block progress in arms control negotiations for many years. Some then argue that university scholars, as a matter of principle, should not accept contracts to further the research programs of the SDI.

It is by no means certain that these essentially political feelings about the role of the Department of Defense and its R&D program will increase. If international tensions stay high, and if senior officials in

the administration seem reluctant to engage in serious arms control negotiations or other international negotiations, then the concerns could rise. However, they could also fall quite rapidly if, for example, there is substantial progress in the aftermath of the coming Reagan-Gorbachev summit meeting.

It is important to put this set of concerns in perspective. First, to the university scientists whose research is supported by a grant or contract from DoD, there is little difference in the negotiation or spending of funds from DoD from those of other federal agencies. The research proposal will originate with the scientist and will be forwarded to the DoD agency for their decision. The research, by the regulations of most universities, will be be unclassified. Second, for the typical US university DoD is not a major source of support. For example, for Cornell University, with total sponsored and budgeted expenditures for research in FY 1985 of about $200 million, only about 3% came from DoD.

A common question these days is whether DoD should, in its own interest and in the national interest, support more basic research, and more long-range and applied research in universities. With the Mansfield Amendment effectively out of the way, the opportunity to expand this sort of support clearly exists. My own belief is that DoD <u>should</u> substantially expand support of such research. However, there are important qualifications. University research of this type should not be supported as an element in a highly applied program. The programs should be established and operated from a conviction that the DoD and the nation need more such research, and further that the results should be published and available to all. In addition, DoD, and specifically the armed services, should establish or identify research management offices specifically charged to use explicitly allotted

funds to support university research. Procedures for support should be those initially pioneered by ONR: solicitation of research proposals from university scientists and engineers, and peer review evaluation as the essential element in identifying what projects should be funded. The central objective of the program should be generation of new scientific knowledge. Finally, the support program should be clearly independent of the goal-oriented R&D programs of DoD, SDI and others. How much DoD funding might appropriately be applied to support of pure research? Five percent of its total R&D funds might be a reasonable short-term objective. If the program is as important and as well received by universities as I think I would be, an ultimate goal might be somewhere between 7 and 10% of total R&D funding.

Most of the concerns and tensions between DoD and the universities really relate to the broader arena of restrictions on research dissemination and on contacts with foreign scientists that, although sometimes enunciated by DoD, probably emanate from a higher level of government, for example the National Security Council. Also, to the degree that they are successfully imposed, the restrictions would presumably apply to research programs supported by all federal agencies. Special concerns about DoD arise because it is usually the most visible agency in support of various restrictions. It is also particularly concerning because of its size and political influence.

The Strategic Defense Initiative of the DoD, and especially its emphasis on developing weapons to be deployed in space for defensive use, represents a rather special situation. It was initiated by the US president, and its objective is a major change in US nuclear strategy. It is a long-term program that will be in an R&D stage for several years before the feasibility of some of its major technologies is known. The SDI program is goal-

oriented and although formally called research, it is clearly applied, with many components that reasonable people might already call development. For these reasons university research on SDI projects seems inappropriate to many university scientists; other disagree, so that the issue is contentious.

The other concern in universities about the SDI program is that a several billion dollar add-on for SDI to the research budget of the Department of Defense will almost surely lead to a decrease in federal funds for civilian-oriented R&D, and that this will impact on the level university research. This need not happen, and concern about it is doubtless actuated in part by self-interest. However, there is a larger issue in that the need for US development of more high-technology industries is widely voiced in government and business circles, and research programs of universities are usually seen as an important source of the underlying basic and applied science for these new technologies.

What of the Future?

Pessimists will doubtless believe that what we have seen in recent years is a permanent change for the worse, in that the idea of restrictions on R&D results and on visits of foreign scientists will persist, and that the very large budget for military R&D will stay permanently high because of the greatly expanded DoD programs, and the addition of large funding for R&D for the Strategic Defense Initiative. Hence, it can be argued, the outlook for even constant funding for civilian R&D looks pretty grim. I am less pessimistic. The large DoD budgets are primarily a product of the current US administration, and are even now under attack. It is also conceivable that the coming Reagan-Gorbachev summit will start serious moves toward a genuine decrease in levels of nuclear missiles by the two superpowers. If serious moves are started in this direction, all sorts of possibilities

would open up. The critically important Anti-Ballistic Missile Trea could be updated and improved by the US and USSR. Military budgets could decrease. It is even possible to believe that the Star Wars program will turn out to be a bargaining chip in US-USSR negotiations.

Difficulties will remain. The large US budget deficit will impel any subsequent administration to keep a very tight rein on the federal budget, so that increased funding for civilian-oriented R&D may be hard to obtain, even if expenditures for R&D for the military decrease. However, the universities themselves can take actions that will make their position better. They can become more realistic in their analysis of the real costs of research in universities, and with that solid information improve their financing and management of R&D programs. Industry-university collaboration in research may grow significantly. But even with progress in all these, the need for substantial support of university research by the federal agencies will remain.

DISCUSSION

Mr. LUJAN [acting chairman]. Thank you very much, Dr. Long. It is an excellent presentation. It certainly gives the committee a much better view of the research relationship with the universities.

As you were discussing all of these, and you have touched on most of them, but certain thoughts keep going through my mind. One is the national laboratory research versus, if we may call it that, university research as it applies to basic or applied research and then the question of doing classified work at universities.

Could you tie those together for me? When we come up with a report on what our science policy should be, of course, we have to take a look at both ends of the equation, and it would be very helpful if you could take those three thoughts, the universities, labs, basic and applied, and the classified work, if you would just comment on that and tie it all together?

Dr. LONG. The large majority of U.S. universities have a policy that they will not accept classified research on the campuses. The reasons for that, I think, are exceedingly obvious. Having barriers for discussions between one professor and another and a student and his professor are not conducive to good teaching. The basic philosophy of academic scientists is that their research should be published in the open literature and available promptly to everyone. Again, classification is not compatible with that.

So, I personally think that the decision of most universities not to let classified research be on campus should stay. That, by the way, does not mean that lots of individual university scientists don't consult on a classified basis with military groups. I did that myself for many years. I probably still have classification which is a little inactive these days, but I think that eschewing of classified research on university campuses is a desirable thing.

As to the national laboratories, the first point is that the universities, of course, are more than a little involved in these.

For almost the last 40 years, I have been a trustee of something here in Washington called Associated Universities, Inc., and it runs Brookhaven National Laboratory and is involved in the big national radio astronomy programs in the same way. University people take responsibility for it, argue budgets, and are deeply involved in the support. I have taken sabbatical leaves at Brookhaven National Laboratory and have had students work there.

I think that the ones—I always forget this phrase—the GOCO's, of which Brookhaven is one, and the AEC ones in general, I think, saving one problem, have a lot of things going in making them be really good, desirable, effective laboratories.

The only thing that gets into trouble and one of the questioners mentioned this a little earlier is when they lose their mission. If there is some notion that they have an explicit mission and that begins to fade, that is troublesome. It is troublesome to anyone and, indeed, one sees a certain amount of it in universities when senior professors find that they are still working in a field which has got pretty dull. It is not quite a loss of mission but it is certainly a loss of an important mission.

I think that one ought to give—and I think this is very much in David Packard's philosophy—I think one ought to give a good deal

of responsibility to these laboratories to try to build themselves up. I think Mr. Hess' point of saying a strong director and a good deal of independence and a certain generalized accountability but not micromanagement is the way to go.

What you do when the mission really disappears is something else. Myself, I think it is not to this country's credit that we have closed so very few laboratories. Why shouldn't we close laboratories now and then if they have really lost their mission? Why not close or amalgamate and move on to others?

But I think that if one pays attention to missions and pays attention to giving the laboratories the independence they need in hiring and promoting, I think they can be very important.

I do think it is somewhat doubtful how important a role they will play in the competitive buildup of technologies that people talk about as they look upon our commercial situation vis-a-vis the Japanese or the Germans. A coupling of these national laboratories to industry is not all that easy. The picture that a Federal laboratory can develop a process and say "Here it is, Mr. Industry, why don't you take it over and run with it?" really misses the way that industry has worked. I am skeptical of that close linkage.

I do think much more consulting could and should be done by these good people in these Federal laboratories with industry. I would like to see closer relations. I think automatically to believe that they are going to play a large role in commercial technology development is a bit overstated sometimes.

Mr. LUJAN. Do you think that universities ought to run the laboratories as opposed to a private company running the laboratories?

Dr. LONG. I don't have any strong feeling on that. I think that Union Carbide ran Oak Ridge quite well for a good many years. I think that is a somewhat secondary point.

Mr. LUJAN. I come from New Mexico, and the University of California operates Los Alamos. Every time about contract renewal time, there is the question at the university level about whether the university should be operating a weapons laboratory. We always seem to renew the contract, but there is always that.

There is an interesting point that you made about classification and the researchers at universities wanting to talk to one another. One of the subcommittees, the Space Science Applications Subcommittee, was in the Soviet Union just last week. One of the things that we found was very interesting in that the working folks, the scientists, technicians, the program managers, all are most anxious to do cooperative work. As a matter of fact, one of them said to, I guess, their equivalent of the State Department, "If you will give me a visa, I will go tomorrow."

However, when we got to the political level, then we had a little different situation. So, I guess it is a natural tendency for scientists to want to share that information and, of course, that is our system. That is why we are advanced.

Dr. LONG. But I do think we could be, ought to be, more encouraging of collaborative research. There are a lot of areas where it is a natural and clearly would be mutually beneficial. Clearly, meteorology and all the things that have to do with the state of the

world as a total globe are things where collaboration would clearly be desirable, and exchange of data and so on.

I think that the space exploration area is an area where some more collaboration would be sensible. So, there are lots of areas where it won't work very much and lots of areas where I don't think it is much needed, but there are certainly some where it would be beneficial.

Mr. LUJAN. Yes, I certainly agree with you.

I don't have any further questions. We thank you for sharing your ideas with us.

With that, the task force stands recessed until tomorrow morning at 9:30 when we will meet in this room for our fifth hearing on science in the mission agencies and the Federal laboratories.

Thank you very much, Dr. Long.

[Whereupon, the task force recessed, to reconvene at 9:30 a.m., October 23, 1985.]

[Answers to questions asked of Dr. Long follow:]

Cornell University

PROGRAM ON SCIENCE, TECHNOLOGY AND SOCIETY

632 CLARK HALL
ITHACA, NEW YORK 14853-2501
TELEPHONE 607/256-3810

1 November 1985

MEMORANDUM

To: House Committee on Science and Technology
From: F.A. Long FL.
Subject: Answers to questions forwarded to me on the basis of my testimony to the Committee on 22 October 1985

1) How might the optimum balance between civilian and military support for scientific best research best be determined?

Ideally the balance between these two modes of support would be determined by independent evaluation of what was needed for civilian support and what the military services needed for best doing their job. If one thinks specifically of research in US universities and asks this question, the situation is more complex because the majority of the support for university research comes from the mission-oriented agencies of the federal government. The question then becomes, should not these agencies, all of which depend on civilian research for some of their activities, portion out their support in terms of the science content of their missions and in terms of their size? Since DoD is the largest of the federal agencies, and since the science content of its effort is high, it should reasonably be expected to be a large contributor to university research.

2) To what extent does defense-supported research yield technology which is applicable to the civilian sector and vice versa?

The amount of "spin-off" that comes to the US civilian sector from military-supported programs of R&D is a much-discussed question. The percentages usually are given as somewhere between 10% and 20%, meaning that the spin-off is significant but not of major importance. In the reverse direction, the total amount of R&D supported by the civilian sector is so much larger and more pervasive than that of the military, that a better way of commenting is to say that the military activities are essentially built on the available civilian science and technology. A former Assistant Secretary of the Air Force put it this way: "Military systems development in the US... is heavily influenced not only by civilian science and technology, but also by civilian political, social, cultural and economic factors...."

3) Do decreases in civilian research relative to DoD support erode the scientific base, and thus national security?

Probably. Since research and development for the military is essentially built on the larger base of civilian science and technology, anything that erodes the latter will have a negative effect on DoD technical capabilities.

4) How will a "crash program" such as SDI affect the supply and demand of scientists, the scientific community, and the economy?

Analysts of the very large Apollo program to put men on the moon have given evidence that the large demand for scientists and engineers caused shortages, particularly of engineers, and also increased the salaries to a

degree that reacted on the overall civilian activities. The effect of the SDI program, in its R&D stages at least, will probably not be so strong. The total economy is much larger now, so that even if SDI reaches the projected levels of R&D funds (in the order of $6-8 billion per year) its relative impact will not be so great. Furthermore, it is likely that some part of the funds for SDI will come by decreasing other programs within the DoD budget. However, if the SDI program moves from research into development, and from development into production, the impact on the supply of engineers, computer scientists and other technical experts could be very substantial.

5) The US spends about 69% of the federal R&D budget on military R&D, whereas Japan spends about 5% of its government R&D budget on defense-related R&D, and West Germany spends about 15% of its government R&D funds on defense R&D. Does this put the US at a competitive disadvantage relative to Japan and West Germany?

The argument is persuasive that this large imbalance on relative funds spent for military R&D would lead to a less effective overall R&D program for the US, and perhaps therefore to a competitive disadvantage. Also, the fact that a substantial fraction of US scientists and engineers work on military projects would seem to point in the same direction. However, the question of what makes for a competitive industrial advantage of one country to another is so complex that I am hesitant to attribute a disadvantage simply to these factors.

6) Some university researchers argue that no university scholars should accept contracts to further the research programs of the SDI; how can such a stance be reconciled with the universities' tradition of academic freedom?

Arguments like this belong in the same category as the urgings on campuses that university faculty should "vote Democratic" or "vote Republican." They express a sentiment of a group, but are totally unbinding. At any university I know of, a faculty member may accept a grant or contract from any DoD agency, including SDI, and work on it assuming only that it meets the normal university criteria, e.g., to be unclassified and to contain no restrictions on publication. No question of academic freedom is involved in this.

7) Could you please estimate the amounts of basic and applied research supported by the Defense Department that are classified confidential or secret?

My estimate is that very little of the basic research supported by DoD is classified, and I suspect that only a fraction of the applied research is classified. The DoD classification makes a precise answer somewhat difficult. The latest report by the Undersecretary of Defense Research and Engineering, released in March 1985, states that out of a total RDT&E budget of $31,452 million, only $861 million were for research. Since roughly 2/3 of this was spent in universities, one can assume that the large fraction of this category was unclassified. In contrast, over 80% of the budget for RDT&E fell in the categories advanced development, engineering development and operational systems development, and it is reasonable to assume that the large fraction of these expenditures were classified.

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

WEDNESDAY, OCTOBER 23, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SCIENCE POLICY TASK FORCE,
Washington, DC.

The task force met, pursuant to notice, at 9:39 a.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua, chairman of the task force, presiding.

Mr. FUQUA. The task force will be in order.

This is the fifth of our hearings on science in the mission agencies and Federal laboratories. This hearing will examine science policy in the Department of Defense.

The first of our distinguished witnesses will be Dr. Gerold Yonas, Acting Deputy Director and Chief Scientist of the Strategic Defense Initiative Organization. Dr. Yonas will explain the SDIO's policy on basic and applied research and the organization's relationship with the research community.

We are pleased to hear from you this morning, Dr. Yonas. We also have three other very distinguished witnesses from whom we will hear in the course of the morning.

STATEMENT OF DR. GEROLD YONAS, ACTING DEPUTY DIRECTOR AND CHIEF SCIENTIST, STRATEGIC DEFENSE INITIATIVE ORGANIZATION, WASHINGTON, DC

Dr. YONAS. Good morning. It is a pleasure to be here this morning and talk to you about some of the management issues in SDI related to science in the missions agencies and to answer your questions.

I would like to submit my written testimony for the record and to speak, hopefully more briefly, emphasizing some of the highlights in that.

Mr. FUQUA. We will make your statement in its entirety part of the record.

Dr. YONAS. Thank you.

Although the SDI is a rather new organization and it is confronting a very important challenge that has enormous implications for our Nation as well as the entire world, it is surprising when you realize how small the organization really is. This organization was established in 1984 and is a separate agency with its director, Lt. Gen. James Abrahamson, reporting directly to the Secretary of Defense. This organization began a little more than a year ago with a

staff of almost two dozen people with roughly a half a dozen technical people on the staff. The organization has been growing rapidly. Right now, we have close to 125 people, and we expect to be at a 200 person level at the end of this fiscal year.

Nevertheless, this is a program which is managing in fiscal year 1986 a budget, although we don't have an appropriation yet, hopefully in the vicinity of $2.7 billion, and we expect to do this with a relatively small staff.

I will talk some more about the management of the program later, but first let me emphasize the charter of the program. From our charter, we have the language that we are to manage and direct the conduct of research through advanced technology programs that will provide the technological basis for an informed decision regarding the feasibility of eliminating the threat posed by ballistic missiles and increasing the contribution of defensive systems to U.S. and allied security.

Now, this mission, this mission which is not development and is not deployment, is a mission to do research. However, this research is focused, and we expect that this focus will remain for the next 5 years, and that is to provide a sufficient understanding of the possibilities that advanced technology can bring to bear on these problems so that we can make a decision on going beyond the research phase.

If this research is successful, then we think the resulting defense system, although not performing in any sense perfectly, should nonetheless provide the basis for a transition to a safer and more secure world based on increasing reliance on defense. So, our aim is to have in the early nineties the data base. The data base will allow us to extrapolate from that data into a survivable, reliable, and cost-effective defense.

In order to acquire that data base, we think we will have to call upon all of the sectors of the scientific and engineering community. I am not sure how we are going to divide up those funds over that 5-year period, but in fiscal year 1985, we invested about 5 percent of those funds in the university community, about 20 percent of those funds in the Federal Government organizations—the national labs, Federal contracts, the research organizations—and the bulk of the funds, about 75 percent, in industry.

The mix of those funds is now preordained. It is defined through a competitive process. This competitive process is the keystone to the entire SDIO approach.We begin with analysis and system architectures, the backbone, the fundamental of the entire program, to define requirements. Those requirements then are used to create the areas and topics of research. We provide that requirement to the scientific and engineering community, and we request proposals. These proposals then are taken in, although we do get on occasion unsolicited proposals, and they are evaluated in terms of deliverables, cost, schedule. Then, within the fiscal limits imposed by the Congress, we proceed with the program.

That brings me to the next topic. Those fiscal limits have resulted in the requirement, the natural requirement, of course, to set priorities. Priority setting has continued to be one of the major activities that we carry out in this central management organization.

These priorities are not made in an exclusive way independent of other organizations in the Government. First of all, we consult with the various offices within the Secretary of Defense's organization. Then we deal with other relevant agencies, the Defense Nuclear Agency, the National Aeronautics and Space Administration, the Department of Energy [DARPA]. We have to and we consistently consult with the SDI commands within the armed services: the Army, Navy, and the Air Force. We consult with various offices of the executive branch, the Office of Science and Technology Policy, the OMB, the NSC, the State Department.

To show you the degree to which we coordinate the program, I want to point out that we recently carried out an extensive review with the White House Science Council of the Office of Science and Technology Policy. We carry out frequent reviews with the OMB, and we have a consultation and advice provided onsite to the negotiating team in Geneva. So, this priority setting is a complex process which involves coordination with many branches of the Government.

In order to facilitate this coordination, we have asked many of these organizations to form their own SDIO-related focal points. This allows us to carry out our central management role and deal with these agencies. Although we expect we will have probably 200 people at the end of this fiscal year in managing this program, we expect that at the same time, there will be well over 1,000 individuals in these various agencies managing these programs.

In fiscal year 1985, as a result of this decentralized management approach, we were able to begin procurement of roughly 1,000 contracts, and we were able to obligate almost 100 percent of the funds appropriated to us.

We think that this decentralized approach has been successful thus far only because of the total dedication and the very valuable cooperation of these many agencies. We are grateful to all of them for helping us manage this program.

The question of how you manage research in this kind of a complex environment and for rapidly changing technology is an interesting and a challenging process, and I think we are learning constantly. We are dealing with various agencies. We are dealing with complex problems. In order to do this, we have tried to rely on advisory groups to provide the breadth of experience and technical expertise into our decisionmaking process.

The most central advisory group in our program is the SDI Advisory Committee which consists of leaders of science and engineering throughout the country. That committee is chaired by Prof. Frederick Seitz. That committee meets quarterly and reviews various programs, makes suggestions for increasing certain activities or decreasing activities, and occasionally that committee forms subcommittees of its own to look in-depth at certain research areas.

In addition to that central committee, the SDI Advisory Committee, we also have committees in support of the battle management and command and control functions of our program. We have also several committees on sensors, innovative science and technology, and directed energy. We believe that this committee approach is very useful to providing the kind of detailed understanding and flexible management within a small central organization.

In addition to dealing with these committees that we charter and where we decide who is on these committees, we also believe that it is important in this kind of a program to consistently deal with not only our friends but also people who are opposed to the program who may have contrary views. So, we have tried to engage in detailed discussions with the proponents as well as the critics.

One interesting organization that has been very valuable to the defense research in this country for many years is the Jason organization. We realize that in the Jason organization we know there are people who are visible, vocal critics of the SDI.

Nevertheless, we have engaged the Jasons in looking at critical problems. We have given them detailed reviews and briefings of the key areas in our program. We have asked them to emphasize some of those areas that we call the long poles, the critical paths in the program. Last summer, we asked them to look at such issues as computer software and midcourse discrimination.

We also provide comprehensive briefings and information to other groups that are carrying on reviews of our program. We work very closely with the Office of Technology Assessment that recently completed a review of our program and published its report. Right now, we are working very closely with the American Physical Society. They are carrying out a review of the directed energy weapon program. We are working closely with them.

Now, let's get back to the management issues. This is a new program, as I mentioned, and it is approaching a very ambitious task. In proceeding with this program, we have not emphasized the process. We have emphasized results, and we have employed various funding mechanisms to get a very rapid startup. Because the diversity of the program, the fact that we are dealing with national laboratories, large industry, small business, universities, we find that innovation in getting these programs going has been extremely important.

We are also actively engaged at this time in discussions with Allied governments. In this area, what we are trying to do is to establish mechanisms for these Allied researchers to participate in the program. The goal there is to get the product in the most effective and most rapid and most cost-effective manner, and we think there is a great deal of technological capability that our Allies can provide to the program.

We think that our flexible management approach has allowed us to accelerate the startup over what might have been possible if we had spent the first year establishing a centrally-executed approach. Instead, we chose the centrally-managed and decentralized execution approach.

One of our problems has been a lack of hard data, a lack of a good way to measure the effectiveness of this startup, so we have had to create new ways to collect data to try to understand how well we are doing. One problem we have had is in measuring the rate of expenditures.

There are two traditional ways people talk about managing or monitoring the rate of expenditures. One is the rate of obligation—that is basically when you sign contracts. The other is the rate of expenditures—that is when you pay the bills. The problem is the

long lag time between when the work is done and when the bills are actually paid.

What we have done is to have gone out to our decentralized agencies who are actually executing the program and asked them to collect data on when work is actually completed, not necessarily when the bills come up through the chain of accounting into the system. What we have found is that this approach to determining when these non-cancelable commitments are made, when it is that the work is actually done and you can't pull back from the work but the bills aren't in, is extremely important in managing the program.

May I have the viewgraph?

We see, for instance, a very large disparity between the obligations and the expenditures. If we just looked at the expenditure curve, we might be much more reserved in terms of making our plans and our commitments for the future years. But we think that using this technique of noncancelable commitments in which we really determine what it is that has been done is extremely important and we would like to urge that the accounting procedure might be improved to provide more of a direct information to the Government in terms of what has been done, not necessarily what has been built.

FY85 TOTAL SDI FUNDS STATUS

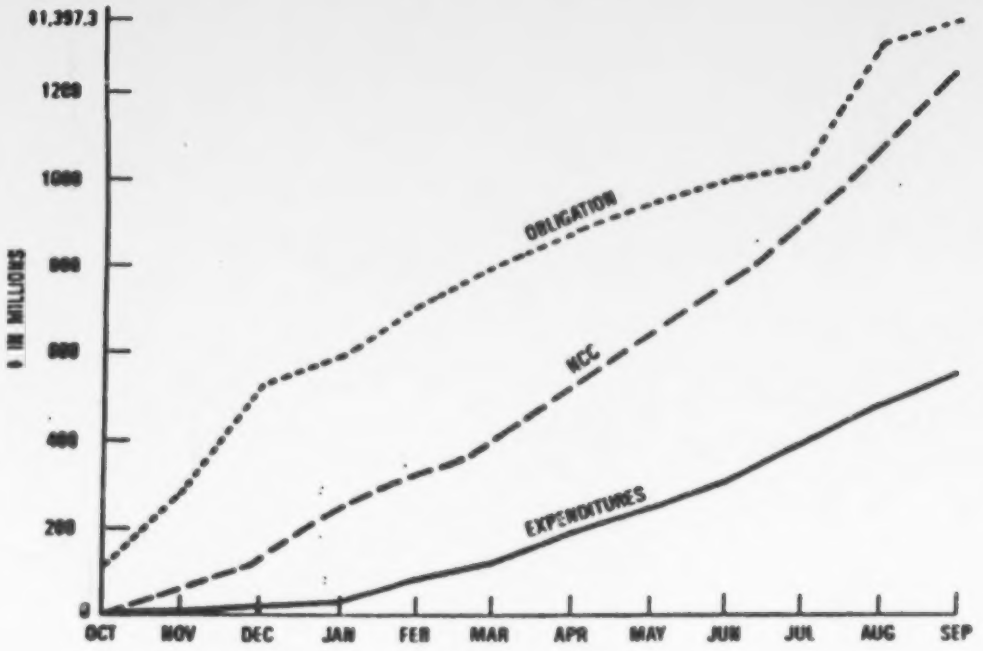


FIGURE 1

This lag time, I think, can give disturbing or false impressions of where you really stand in a program.

I wanted to give the impression that this is a fast-paced program, and we are trying to carry out innovative approaches to managing this program, but I don't want to give the impression that it is a crash program. In no way is it a crash program. It is an accelerated program. We like to think of our program as a horse race, a horse race among ideas. We like to think of the program as being a very fast track for this horse race, but we don't think it is a crash program.

We think that these techniques for getting on with competition, moving rapidly into new ideas, is a way to facilitate rapid technological advance. We think that is advantageous over some of the go-slow approaches which have existed and which have built up in the Government for some time.

We realize that, in this process, where we are pressing forward and making demands on the science and technology base, and where we are setting priorities where occasionally, within the limited funding, we have to make decisions that some people may think are premature. But we believe it is necessary to press forward and to not allow the time scale to continually stretch out with higher costs and less performance. We think it is important to admit the risk and press on.

In doing this, we have found in the community a tremendous amount of reserve capability, that there is a real basis of creativity and technical capacity that is really sitting there and waiting for a challenge. We believe that this capacity, this American technological capacity, one of the greatest strengths of this country, can really be brought to bear when it can focus its attention, and it is that focus that really makes the difference.

We think the SDI has provided the kind of focus which has an inherent basis of an ethical and a logical goal. It is that focus that we think is really allowing this community to bring its attention to bear and to move forward rapidly.

We also think this is an extremely timely moment. Because of the previous technological advances, we think we are ready to exploit those advances. They are in many areas: computer hardware, software, materials science, sensors, optics, propulsion, power supplies, lasers, accelerators—advances that have taken place over the last dozen or so years. We think we are ready to move forward with this focused approach to take advantage of this opportunity.

One of the most frustrating parts of managing and being involved in management of this program is not being able to really tap that capability that is really out there. We find that there are facilities that could be modified. We find that there are people out there ready to go, and we think that we can sustain a very rapid startup involving the entire technical community.

That includes the universities. Because of the research nature of this program, we think the universities can play an important role.

We think that there has been some misunderstanding in our relationship with the universities, and I wanted to talk about that. The next viewgraph shows the way we are organized. We have several principal elements of the program that deal with specific topics. The universities usually deal with these program elements

through a third party. For instance, they subcontract, or a minor part of the larger program is dealing with one of these major program elements.

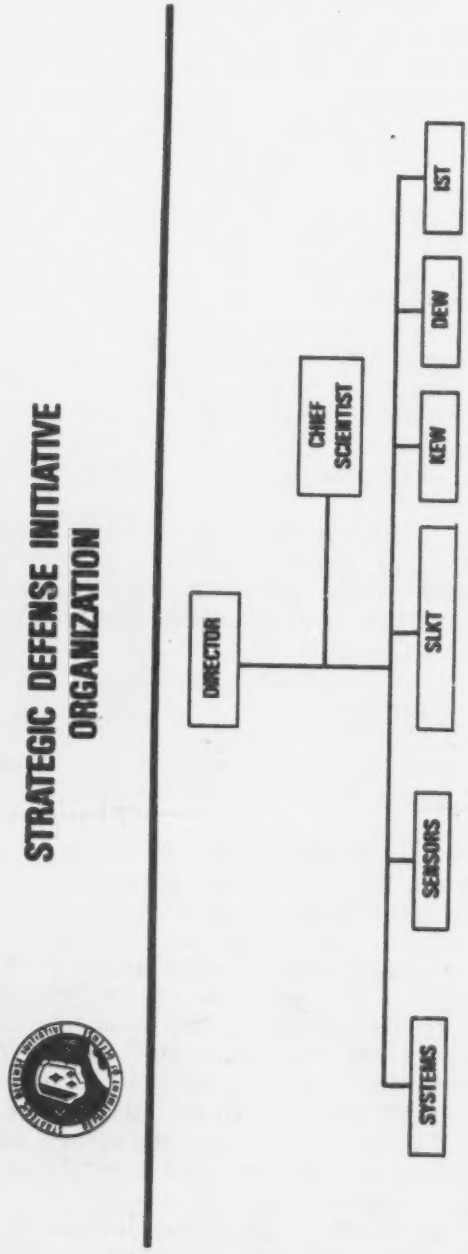


FIGURE 2

One part of our program, the Innovative Science and Technology Program, really has a special role in terms of the university relationship. Why have an innovative science and technology program?

I was involved in the Fletcher study in the summer of 1983 and Harold Agnew, who was the deputy in charge of that summer study coined an expression at that time in regard to high technology. As you know, Harold Agnew was the Director of Los Alamos and the president of General Atomics. He said the problem in technology is that the hogs always trample the piglets on the way to the trough. What he was talking about was the fact that large programs quite often, once they get started, squeeze out the opportunity for the really smaller innovative groups to really get started and to feed into this entire process.

So, when we started the SDI, we created an organization called Innovative Science and Technology which was to have specially earmarked funds fenced off, protected funds, no matter what happens in shortfalls or programs in the big activities, would have a few percent. Our goal is to have as much as 5 percent earmarked for this seed money, this seed corn of ideas to flow into the other program elements.

We are looking at many advanced areas, short wavelength lasers, advanced sensing and computing techniques, advanced materials such as composites and high-energy density propellants, molecularly-engineered dielectrics for very high-energy density energy storage, various techniques for innovative ways to store energy and condition power to very high levels. We find that there is a resident need to have this kind of—in the areas related to SDI—to have this independent and innovative research organization which can pursue these ideas, hopefully on a level that gets the programs going, that shows that these ideas are feasible and then transfers them to the program elements which are more specifically mission oriented.

Last spring, this organization, the Innovative Science and Technology organization, sponsored a conference for universities. Over 150 universities or academic institutions were represented. What came out of that were thousands of white papers. We asked for brief papers defining what it is, their ideas, what they wanted to do, how long it would take, and what would be the payoff.

What we found is that there really is a tremendous resident desire to proceed with pursuing these ideas on behalf of the SDIO. We think that speaks volumes about the program and the support from the university community and should be contrasted with some of the community that has in fact distributed petitions and spoken out against the program.

So, we don't think the academic community has just one voice, and I think that those thousands of white papers speak to at least part of that vocal community.

Now, that community does have concerns about the SDI. That concern has to do with their ability to publish their work. What we have done is emphasized in the Innovative Science and Technology organization that conduct of fundamental research—and the definition of fundamental research is available in the national security directive 189—and we believe that we can carry out this fundamental research. First of all, let me mention it is not just an emphasis

on the academic institutions, but we think this fundamental research can come from small business, from industry, from large industry. The point is that this fundamental research is, we think, vital seed corn for the ideas and for the technologies of tomorrow.

One of the problems that has arisen in regard to pursuing this fundamental research is the fact that when we began this program, we established the IS&T with the category of 6.3 which is a budgetary category within the Department of Defense. Normally, that work going on under 6.3 is normally not allocated for fundamental research. We tried to clarify that. Hopefully, we have clarified that issue in memos which have been published by our group, and we expect that as we proceed will provide the universities with the opportunity and the freedom for free publication of their fundamental research.

The second issue that the universities have raised with us is that because of the fact that we announced the award of grants, we apparently incorrectly implied some political support from the academic institutions ourselves. I would like to say categorically that was never our intention. We did not intend to somehow give the impression that we had received political support from the institutions.

Basically, what we have tried to do is create consortia, groups of researchers working at universities or academic institutions, not consortia of institutions themselves. In the future, we will be very careful to emphasize in our public statements that the research is being carried out by consortia of researchers and not consortia of institutions.

Another issue has to do with availability of the manpower to actually pursue this activity of research. Clearly, this is a concern for the entire Department of Defense. In fact, Don Carter testified on October 2 on the availability of personnel for the entire DOD, but I wanted to call your attention to a House Appropriations Committee study that was carried out last year in which they used their independent investigating staff to look at the requirements for SDI in particular. They concluded that the SDI did not tax the available resource base.

Now, there are clearly some areas of specific need, some areas where there are some requirements for additional personnel. For instance, one is in optical science. Here we have only two institutions that award the Ph.D in optical sciences, the University of Arizona and Rochester University. Here we do have some concern about available personnel. But we think there is a great deal of flexibility in the community. People trained broadly in engineering and science can move over to other fields where there are needs. This flexibility, we find, is one of the strengths in our technological society in this country, the fact that we have individuals at large companies that go off and form small business, professors at universities that move around. We have the flexibility to retrain and to fill the needs in research organizations. I wouldn't take as a given that if we don't have at a particular point in time the people in a certain field, because in our flexible and mobile society, people move and they fill in those gaps. We have a marketplace that works.

The real limitations in the program are really the realistic limitations on the rate at which technology can move. It can only move so fast. And the real limitations which are provided by fiscal constraints, how much money is available.

Right now, we don't think that the ABM Treaty compliance issues limit the pace at which the program can move forward. In fact, we plan to carry out this research in compliance with the ABM Treaty. In fact, the President recently announced or reemphasized his desire that we use the more restrictive interpretation of the ABM Treaty as we proceed with our research.

Let me say one word about the Federal laboratories. I think a very useful document is the Federal laboratory review panel report that was issued in May of 1983 that spoke to the role of the Federal laboratories. We believe that the Federal laboratories have an important role to play in our program in those special areas where, because of their unique or capital intensive or long term multidisciplinary nature, have a special role to play in the program. We are going to continue to rely on the national labs.

Let me say, finally, that we think there are important attributes that are necessary to pursue this program. One is the dedication to get the answer. Second is the creativity that is needed in this kind of a new field of exploration. Finally is a healthy skepticism, because going in we know there are going to be a lot of approaches which are not going to pan out.

We think we have, in pursuing this program, these three attributes of dedication, creativity, and skepticism. We also think because of the strong motivation that is provided by the goal, by the ethical and logical goal to pursue a more secure and stable future, we think the SDIO is on its way to getting the answer for the country.

Thank you.

[The prepared statement of Dr. Yonas follows:]

STATEMENT ON

THE STRATEGIC DEFENSE INITIATIVE SCIENCE IN THE MISSION AGENCIES & FEDERAL LABORATORIES

BY

DR. GEROLD YONAS

ACTING DEPUTY DIRECTOR AND CHIEF SCIENTIST

STRATEGIC DEFENSE INITIATIVE ORGANIZATION

BEFORE THE

SCIENCE POLICY TASK FORCE

COMMITTEE ON SCIENCE & TECHNOLOGY

HOUSE OF REPRESENTATIVES

99TH CONGRESS, FIRST SESSION

OCTOBER 23, 1985

MR. CHAIRMAN:

I WANT TO THANK YOU FOR GIVING ME THE OPPORTUNITY TODAY TO ADDRESS YOU ON THE SUBJECT OF "SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES."

MISSION

ALTHOUGH THE SDIO IS UNDOUBTEDLY ONE OF THE NEWEST AND SMALLEST OF THE RESEARCH ORGANIZATIONS WITHIN THE FEDERAL GOVERNMENT WE ARE CONFRONTING A TECHNICAL CHALLENGE THAT HAS ENORMOUS IMPLICATIONS FOR OUR NATIONAL, AND INDEED WORLD SECURITY AND SURVIVAL. WE WERE ESTABLISHED AS A SEPARATE AGENCY OF THE DEPARTMENT OF DEFENSE IN 1984, AND OUR DIRECTOR, WHO IS APPOINTED BY AND REPORTS DIRECTLY TO THE SECRETARY OF DEFENSE, IS LIEUTENANT GENERAL JAMES ABRAHAMSON. LITTLE MORE THAN ONE YEAR AGO WE HAD A STAFF OF TWO DOZEN PEOPLE, INCLUDING SIX PROFESSIONAL TECHNICAL PEOPLE AND TODAY WE HAVE ROUGHLY 125 PERSONNEL AND HAVE ESTABLISHED A PLAN TO REACH A LEVEL OF 200 PEOPLE BY THE END OF THIS FISCAL YEAR.

THE SDI MISSION IS SUCCINCTLY STATED AS FOLLOWS:

> SDIO SHALL MANAGE AND DIRECT THE CONDUCT OF RESEARCH THROUGH ADVANCED TECHNOLOGY PROGRAMS THAT WILL PROVIDE THE TECHNOLOGICAL BASIS FOR AN INFORMED DECISION REGARDING FEASIBILITY OF ELIMINATING THE THREAT POSED BY BALLISTIC

MISSILES AND INCREASING THE CONTRIBUTION OF DEFENSIVE SYSTEMS TO U.S. AND ALLIED SECURITY. THE PROGRAM SHALL PROVIDE OPTIONS FOR NEAR-TERM DEPLOYMENT OF LIMITED BALLISTIC MISSILE DEFENSES. THIS PROGRAM WILL BE CARRIED OUT IN FULL CONSULTATION WITH OUR ALLIES AND IN COMPLIANCE WITH ALL EXISTING TREATY OBLIGATIONS.

RESEARCH BUDGET

THE COMMITTEE HAD ASKED FOR AN INDICATION OF HOW MUCH OF THE SDIO BUDGET IS SPENT ON RESEARCH. THE ANSWER IS ALL OF IT. THE PRESENT MISSION OF THE SDIO IS RESEARCH, BOTH BASIC AND APPLIED. THE RESEARCH, HOWEVER, IS FOCUSED. THE FOCUS FOR THE NEXT FIVE YEARS IS TOWARD A SUFFICIENT UNDERSTANDING OF THE POSSIBILITIES THAT NEW ADVANCED TECHNOLOGIES CAN BRING TO BEAR IN PROVIDING A DEFENSE AGAINST ICBM'S. IF OUR RESEARCH IS SUCCESSFUL, THE RESULTING DEFENSE, WHILE PERFORMING LESS THAN PERFECTLY, SHOULD NONE-THE-LESS PROVIDE THE BASIS FOR A TRANSITION TO A SAFER AND SECURE WORLD BASED ON "INCREASING RELIANCE ON DEFENSE." WE HAVE NOT STRAYED FROM THE ORIGINAL GOAL SET FORTH BY THE PRESIDENT IN MARCH 1983. OUR AIM IS TO HAVE IN HAND BY THE EARLY 1990'S A DATA BASE THAT, IF IT PROVES THE MISSION IS FEASIBLE, COULD EXTRAPOLATE INTO A SURVIVABLE, RELIABLE, COST-EFFECTIVE STRATEGIC DEFENSE FOR THE UNITED STATES AND ITS ALLIES.

WE WERE ASKED TO ADDRESS THE QUESTION OF HOW OUR BUDGET WAS DIVIDED AMONG UNIVERSITIES, GOVERNMENT LABORATORIES, AND

INDUSTRY. THE DIVISION OF THE FY 1985 BUDGET OF $1.3973 BILLION WAS AS FOLLOWS:

UNIVERSITIES	5%
GOVERNMENT (NATIONAL LABS + FEDERAL CONTRACT RESEARCH CENTERS + ADMINISTRATIVE COSTS)	20%
INDUSTRY	75%

THE MIX OF THESE FUNDS IS DETERMINED PRIMARILY THROUGH A COMPETITIVE PROCESS WHEREBY SPECIFIC MISSION REQUIREMENTS GENERATE AREAS OF RESEARCH THAT ARE DEFINED FOR THE SCIENTIFIC AND ENGINEERING COMMUNITIES, AND PROPOSALS TO PERFORM THIS RESEARCH ARE REQUESTED. (ON OCCASION, INDEPENDENT UNSOLICTIED CONCEPTS ARE PROVIDED TO US BY THE TECHNICAL COMMUNITY.) THOSE CONCEPTS THAT ARE EVALUATED TO BE MOST RELEVANT AND PROMISING IN TERMS OF DELIVERABLES, COST AND SCHEDULE, ARE FUNDED WITHIN THE FISCAL LIMITS IMPOSED BY CONGRESS.

FUNDING PRIORITIES

PRIORITIES FOR FUNDING ARE SET BY THE SDIO DIRECTOR IN CONSULTATION WITH: (1) THE OFFICE OF THE SECRETARY OF DEFENSE; (2) OTHER RELEVANT AGENCIES (E.G., DEFENSE NUCLEAR AGENCY (DNA), NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA), DEPARTMENT OF ENERGY (DOE), ETC.); (3) SDI RESEARCH COMMANDS OF THE ARMED FORCES; AND (4) THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

(OSTP), OFFICE OF MANAGEMENT AND BUDGET (OMB), NATIONAL SECURITY COUNCIL (NSC), AND STATE DEPARTMENT. IN ORDER TO FACILITATE THESE INTERACTIONS, MANY OF THESE ORGANIZATIONS HAVE ESTABLISHED AN INTERNAL FOCAL POINT TO DEAL WITH SDI ACTIVITIES. THE SDI PROVIDES CENTRAL MANAGEMENT BY SETTING OVERALL DIRECTION, PRIORITIES, AND BUDGETS, AND THE AGENCIES LISTED ABOVE PROVIDE DECENTRALIZED EXECUTION OF THE VARIOUS PROGRAM ELEMENTS. THESE AGENCIES SERVED AS THE PROCUREMENT AGENT FOR MOST OF THE OVER 1000 CONTRACTS PLACED IN FY 1985.

SOME RESEARCH PROJECTS ARE REVIEWED WITHIN THESE AGENCIES, OTHERS ARE REVIEWED BY PANELS OR INDIVIDUALS OUTSIDE OF THE GOVERNMENT. THE ONE AREA MANAGED DIRECTLY BY THE SDIO IS SYSTEMS ANALYSIS (THE ARCHITECTURE DEFINITION TASK) AND AN AREA MANAGED ALMOST ENTIRELY OUTSIDE OF THE SDIO IS THAT OF INNOVATIVE SCIENCE AND TECHNOLOGY.

ADVISORY COMMITTEES AND WORKING GROUPS

THE SDIO HAS CREATED A NUMBER OF ADVISORY GROUPS. THE SDI ADVISORY COMMITTEE (SDIAC), WHOSE MEMBERSHIP IS SHOWN BELOW, MEETS QUARTERLY AND HELPS REVIEW THE PROGRESS OF VARIOUS PROGRAM ELEMENTS AND INDICATES AREAS REQUIRING EITHER INCREASED OR DECREASED RESEARCH EMPHASIS. IN FACT THIS COMMITTEE HAS, UPON OCCASION, ORGANIZED ITS OWN SUBCOMMITTEES TO DELVE IN GREATER DEPTH INTO SUBJECTS OF TIMELY INTEREST AND IMPORTANCE TO THE SDI MISSION. THE SDIAC REPORTS DIRECTLY TO THE AGENCY DIRECTOR.

SDI ADVISORY COMMITTEE MEMBERSHIP

DR. FREDERICK SEITZ, CHAIRMAN

MR. JAMES C. ELMS

MR. ROBERT R. EVERETT

DR. JAMES C. FLETCHER

DR. HANS MARK

DR. RICHARD MONTGOMERY

DR. WILLIAM NIERENBERG

DR. MARSHALL ROSENBLUTH

GENERAL BERNARD SCHRIEVER (USAF, RET)

DR. ROBERT SPROULL

DR. EDWARD TELLER

IN ADDITION, THERE ARE SEVERAL ADVISORY GROUPS WORKING AT OTHER LEVELS IN THE SDIO. A LISTING OF THESE WOULD INCLUDE: THE EASTPORT GROUP (BM/C^3 SOFTWARE), SCIENCE AND ENGINEERING SUPPORT GROUP (SENSORS), GOVERNMENT COORDINATING PANEL (IS&T), AND THE DIRECTED ENERGY PROGRAM ASSESSMENT GROUP (DEO). THESE GROUPS PROVIDE INDEPENDENT REVIEW AND ADVICE TO SDI MANAGEMENT IN SPECIFIC RESEARCH DISCIPLINES.

IT IS VITAL TO THE GOOD HEALTH OF ANY RESEARCH ORGANIZATION THAT IT MAINTAIN CONSTANT CONTACT WITH "UNBIASED" OUTSIDE OBSERVERS WHOSE COMPETENCE AND EXPERTISE CAN BE QUICKLY BROUGHT TO BEAR ON MAJOR ISSUES. CONSTRUCTIVE ENGAGEMENT WITH BOTH FRIENDS AND CRITICS IS IMPORTANT. DURING FY 1985 WE ALSO

SUPPORTED THE JASONS WHO REVIEWED SEVERAL SDI SUBJECTS WITH SPECIAL EMPHASIS ON SUCH KEY PROBLEMS AS DISCRIMINATION AND COMPUTER SOFTWARE. IN ADDITION, WE PROVIDED INFORMATION TO THE OFFICE OF TECHNOLOGY ASSESSMENT, AND THE AMERICAN PHYSICAL SOCIETY FOR USE IN THEIR RESPECTIVE EVALUATION REPORTS.

MANAGEMENT

IN THE SDIO, DUE TO ITS RELATIVELY "NEWNESS," AND IN KEEPING WITH A PHILOSOPHY EMPHASIZING RESULTS RATHER THAN PROCESS, WE HAVE USED VARIOUS FUNDING MECHANISMS AND PROGRAM MANAGEMENT TOOLS TO OBTAIN SPECIFIC RESEARCH RESULTS. AT THE PRESENT TIME SDI EFFORTS ARE PURSUED IN NATIONAL LABORATORIES, LARGE INDUSTRY, SMALL BUSINESSES, AND UNIVERSITIES. WE ARE ALSO ACTIVELY ENGAGED IN DISCUSSIONS WITH ALLIED GOVERNMENTS IN ORDER TO ESTABLISH MECHANSIMS TO ENGAGE OUR ALLIES' TECHNICAL CAPABILITIES IN SOLVING THE MOST PRESSING OF THE SDI RESEARCH PROBLEMS.

OUR MANAGEMENT APPROACH HAS ALLOWED THE SDIO TO ACCELERATE OUR START UP OVER WHAT WOULD HAVE BEEN POSSIBLE GIVEN A MORE CENTRALLY EXECUTED PROGRAM. IN THIS REGARD I WOULD LIKE TO DISCUSS WITH YOU FOR A MOMENT A NEW MEASURE OF EFFECTIVENESS THAT WE HAVE RECENTLY EMPLOYED IN SDIO, AND THAT WE BELIEVE MORE ACCURATELY REFLECTS COMMITTED PROGRAM FUNDS. IN MOST NEW PROGRAMS THE ANALYSIS AND MONITORING OF FUNDS IS HAMPERED BY A LACK OF REAL TIME INFORMATION ON THE STATE OF COMMITMENTS. TO

REMEDY THIS WE HAVE DONE TWO MAJOR THINGS. FIRST, WHENEVER IT BECOMES APPARENT THAT A PARTICULAR RESEARCH PROGRAM HAD PROMISED MORE THAN IT COULD LEGITIMATELY DELIVER IN A GIVEN YEAR, WE HAVE REALIGNED FUNDS IN SUCH A MANNER AS TO ENHANCE THE PROJECTS WHICH COULD USE ADDITIONAL FUNDS. IT IS EXTREMELY IMPORTANT TO RETAIN THIS KIND OF FLEXIBILITY IN A FAST PACED PROGRAM SUCH AS THE SDI.

SECONDLY, WE HAVE DEVELOPED, WHAT WE BELIEVE TO BE A NEW MEASURE OF PROGRAM EFFECTIVENESS. THIS NEW MANAGEMENT TOOL IS CALLED NON-CANCELABLE COMMITMENTS. TO UNDERSTAND ITS UTILITY, I WILL TRY TO DESCRIBE ITS FUNCTIONS BY SHOWING THE LIMITATIONS WHICH COME FROM USING THE TRADITIONAL BUDGETARY MILESTONES. KEEPING IN MIND THAT OUR AIM IS TO QUICKEN THE PACE OF OUR PROGRAM BY PUTTING RESOURCES TO THEIR MOST PRODUCTIVE USE, ONE FINDS THAT TRADITIONAL MILESTONES (I.E., OBLIGATIONS AND EXPENDITURES) WHILE STILL IMPORTANT, ARE INADEQUATE. WHY?

OBLIGATIONS:

- ONLY INDICATE WORK IS READY TO BEGIN, NOT THAT IT BEGAN
- INDICATE THE USER HAS BECOME LEGALLY LIABLE FOR PAYMENT OF COSTS
- OCCUR WHEN CONTRACTS ARE EXECUTED OR PROJECTS ACCEPTED

EXPENDITURES:

- OCCUR ONLY AFTER CONSUMPTION...SOMETIMES YEARS LATER
- REPRESENT ACTUAL PAYMENT FOR GOODS/SERVICES

NEITHER OF THESE CATEGORIES BEAR A RELATIONSHIP TO THE "EFFECTIVENESS" OF THE USE OF RESOURCES.

WE BELIEVE NONCANCELABLE COMMITMENTS MAY BE OF GREATER IMPORTANCE, FOR MANAGERS, (NOT NECESSARILY ACCOUNTANTS). NONCANCELABLE COMMITMENTS REPRESENT COSTS AND LIABILITIES INCURRED FOR GOODS AND SERVICES RECEIVED, OTHER ASSETS ACQUIRED, AND PERFORMANCE ACCEPTED, WHETHER OR NOT PAYMENT HAS BEEN MADE. THIS IS A FINANCIAL PARAMETER MORE CLOSELY RELATED TO PERFORMANCE.

NONCANCELABLE COMMITMENTS (NCC):

- REPRESENT WORK ACCOMPLISHED
- INCLUDE INCURRED DEBTS
- INCLUDES BOTH BILLED AND UNBILLED MATERIALS, DELIVERIES AND RESEARCH EFFORTS.
- OCCUR WHEN GOODS/SERVICES ARE RECEIVED, OR WHEN PERFORMANCE IS ACCEPTED...WHETHER OR NOT PAYMENT IS MADE.

IT IS NOT CLEAR THAT THE USE OF NONCANCELABLE COMMITMENTS IS USEFUL FOR EVERY TYPE OF ORGANIZATION, SO I AM NOT HERE TODAY TO RECOMMEND ITS WIDE SPREAD USE OR ADOPTION. ITS USE IS AN EXPERIMENT ON THE PART OF SDIO MANAGEMENT TO TRY TO BE MORE EFFECTIVE THROUGH THE IMPLEMENTATION OF INNOVATIVE MANAGEMENT TOOLS.

AS AN EXAMPLE, I SHOW IN FIGURE #1, THE FY 1985 TOTAL SDI FUNDS STATUS AS A FUNCTION OF MONTHS INTO THE FISCAL YEAR. WE,

AS A NEW AGENCY, HAVE SOMETIMES COME UNDER CRITICISM THAT WE HAVE NOT AND/OR CANNOT EFFECTIVELY ALLOCATE OUR BUDGET RESOURCES AND THAT THE PROGRAM MAY NOT BE WELL DIRECTED. WHILE NCC DOES NOT MEASURE HOW WISELY THE FUNDS ARE COMMITTED, IT DOES AID THE SDI MANAGEMENT TEAM IN DISCERNING WHETHER OR NOT RESOURCES ARE BEING COMMITTED IN A TIMELY FASHION BY OUR PROGRAM MANAGERS OUT IN THE FIELD. LET ME EMPHASIZE THAT THE USE OF NCC DOES NOT REPLACE THE NEED TO MEASURE A PROGRAM BY ITS RESULTS. THE RESULTS ARE WHAT REALLY COUNT AND I WILL HAVE MORE TO SAY ON THAT LATER IN MY TESTIMONY.

TO COME BACK ON TRACK FROM THIS BRIEF DIGRESSION, LET ME ATTACK THE QUESTION OF HOW POLICY AND BUDGET AGENCIES INTERACT WITH SDIO. THE WHITE HOUSE SCIENCE COUNCIL, WHICH REPORTS DIRECTLY TO DR. GEORGE KEYWORTH, THE DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP), RECENTLY PERFORMED A COMPREHENSIVE REVIEW OF THE SDI TECHNICAL PROGRAM. IN ADDITION, WE WORK CLOSELY WITH OMB TO COORDINATE EFFORTS AMONG AGENCIES AND TO MAXIMIZE PROGRAM EFFECTIVENESS.

YOU HAVE ASKED FOR THE IMPACT OF "CRASH PROGRAMS" ON OUR PRODUCTIVITY AND RESOURCES. SIMPLY PUT, NONE OF THE SDI IS ON A CRASH PROGRAM. WE ARE ON ADMITTEDLY A VERY FAST TRACK IN WHAT GENERAL ABRAHAMSON HAS SAID MORE THAN ONCE, IS A HORSE RACE. WE BELIEVE FAST PACED BUT CONTROLLED PROGRAMS, IF ALLOWED

FLEXIBILITY, CAN PRODUCE MORE RESULTS PER DOLLAR INVESTED THAN MOST OF THE "GO SLOW" APPROACHES. HOWEVER, ONLY THE TEST OF TIME WILL REALLY SHOW WHETHER THIS APPROACH TO MANAGEMENT IS PRODUCTIVE ENOUGH TO GET THE JOB DONE.

WE HAVE DETECTED A GREAT DEAL OF RESERVE CAPABILITY AND CREATIVITY WAITING FOR A CHALLENGE. WE BELIEVE THAT AMERICAN TECHNOLOGICAL CAPACITY IS MOST PRODUCTIVE WHEN IT CAN FOCUS ITS ATTENTION ON A GENERALLY ACCEPTED GOAL. THE SDI HAS PROVIDED NOT ONLY THE ETHICAL AND LOGICAL GOAL OF A DEFENSE AGAINST BALLISTIC MISSILES, BUT IT HAS COME AT A TIME WHEN AMERICANS, AND HOPEFULLY THE WORLD, ARE READY TO EXPLOIT THEIR RECENT TECHNICAL ADVANCES. MANY RECENT ADVANCES IN COMPUTER HARDWARE AND SOFTWARE, MATERIALS SCIENCE, SENSORS, OPTICS, PROPULSION, POWER SUPPLIES, LASERS, AND ACCELERATORS ARE READY TO BE EXPLOITED RAPIDLY IN BEHALF OF SDI GOALS.

EXTRAMURAL RESEARCH PERFORMERS

LET ME NOW SHIFT GEARS AND ADDRESS THE SDIO/UNIVERSITY COMMUNITY INTERACTION. THERE HAS BEEN SOME PUBLICITY WITH REGARD TO THIS RELATIONSHIP AND I WOULD LIKE TO TAKE THIS OPPORTUNITY TO SET THE RECORD STRAIGHT.

SOME UNIVERSITIES RECEIVE FUNDING FROM THE PRINCIPAL DIRECTORATES SHOWN IN FIGURE #2, USUALLY THROUGH THIRD PARTY SUBCONTRACTS. BUT BY FAR THE PREPONDERANCE OF UNIVERSITY

RESEARCH ACTIVITY WILL BE FUNDED THROUGH A SEPARATE BUT CROSS CUTTING ELEMENT OF SDIO CALLED THE OFFICE OF INNOVATIVE SCIENCE AND TECHNOLOGY (IST).

THE GOAL OF OUR INNOVATIVE SCIENCE AND TECHNOLOGY PROGRAM IS TO ESTABLISH SCIENTIFIC FEASIBILITY OF REVOLUTIONARY CONCEPTS, CONCEPTS WITH POTENTIAL FOR FULL SDI TECHNOLOGICAL DEVELOPMENT. THIS FORWARD-LOOKING OFFICE HAS A BROAD RESEARCH CHARTER WITH FOCUSES ON SUCH ADVANCED DIRECTED ENERGY CONCEPTS AS GAMMA RAY LASERS, ON NOVEL SENSING AND DATA PREPROCESSING TECHNIQUES, ON ADVANCED MATERIALS FOR SPACE APPLICATIONS, INCLUDING MOLECULARLY ENGINEERED DIELECTRICS, ON INNOVATIONS IN BURST-MODE SPACE POWER AND POWER CONDITIONING, ON EMERGING SPACE SCIENCE APPLICATIONS, AND ULTRA-HIGH SPEED SUPERCOMPUTING. INTEREST IN SUCH AREAS OF SCIENCE AND TECHNOLOGY CLEARLY ILLUSTRATES THAT SDI HAS GREATLY FACILITATED THE MOBILIZATION OF OUR NATION'S SCIENTIFIC COMMUNITY.

LAST SPRING, THIS OFFICE SPONSORED A REVIEW CONFERENCE FOR UNIVERSITIES. OVER 150 ACADEMIC INSTITUTIONS, REPRESENTING 47 STATES, ATTENDED. SUBJECT AREAS INCLUDED COMPOSITE MATERIALS, ROCKET FUELS, ELECTRONIC MATERIALS, SYSTOLIC ARRAY PROCESSING, SOFTWARE DEVELOPMENT, OPTICAL COMPUTING AND SPACE SCIENCE. SINCE THAT REVIEW, WE HAVE RECEIVED OVER 3700 CREATIVE PROPOSALS FROM AROUND THE COUNTRY FOR THIS PROGRAM--PERHAPS THIS IS THE BEST RESPONSE I CAN GIVE TO THOSE STORIES IN THE MEDIA CONCERNING ACADEMICS AND UNIVERSITY SCIENTISTS WHO CHOOSE NOT TO

WORK ON SDI--AND BOTH EXPECT AND UNFORTUNATELY RECEIVE HEADLINES FOR SUCH A DECISION.

TO BE SPECIFIC, THE IS&T OFFICE IS CHARGED WITH CONDUCTING FUNDAMENTAL RESEARCH PROGRAMS FOR THE SDIO (IN ADDITION TO OTHER MISSIONS). THE POLICY OF THE IS&T OFFICE IS TO STRONGLY SUPPORT, ENCOURAGE, AND FACILITATE INVOLVEMENT IN THE SDIO PROGRAM, FROM ALL SECTORS (SMALL BUSINESS, LARGE INDUSTRY, LABS, AND UNIVERSITIES) WHENEVER THE INTEREST, CAPABILITY, AND GOOD IDEAS EXIST IN THAT COMMUNITY. THE NEEDS OF THE SDIO IN THE AREA OF BASIC RESEARCH ARE COMMUNICATED MOST SPECIFICALLY TO ACADEMIA VIA TECHNICAL CONFERENCES, COMMERCE BUSINESS DAILY ANNOUNCEMENTS, WIDELY DISSEMINATED DOCUMENTATION (THE IS&T BROCHURE) DESCRIBING RESEARCH OPPORTUNITIES, AND DIRECT INTERACTION WITH THE COMMUNITY, SUCH AS PRESENTATIONS TO RESEARCH ADMINISTRATORS (SOCIETY FOR RESEARCH ADMINISTRATORS; NATIONAL COUNCIL FOR THE ADVANCEMENT OF SCIENCE; AND NATIONAL COUNCIL OF UNIVERSITY RESEARCH ADMINISTRATORS) AND REGIONAL UNIVERSITY CONFERENCES ORGANIZED BY THE DOD AND ITS BASIC RESEARCH AGENCIES.

COMPETITIVE PROCUREMENTS ARE FUNDED FOR IS&T PROGRAMS AND PROPOSALS ARE REVIEWED WITHIN THE DOD SCIENTIFIC COMMUNITY. THIS INCLUDES PROGRAM MANAGERS AT THE DOD BASIC RESEARCH AGENCIES AS WELL AS SCIENTIFIC PERSONNEL WITHIN THE DOD LABORATORY STRUCTURE. WHEN REQUIRED AGENCIES OUTSIDE THE DOD, SUCH AS NASA AND DOE ARE ALSO USED IN PROPOSAL REVIEW.

AT THIS POINT IN THE DEVELOPMENT OF THE SDIO, NO DIRECT INVOLVEMENT OF THE RESEARCH PERFORMER IN LONG-RANGE PLANNING FOR THE SDIO MISSION OCCURS HOWEVER, BY THE NATURE OF THE RESULTS OF THEIR RESEARCH, THE PERFORMERS INDIRECTLY DETERMINE THE SCIENTIFIC COURSE WHICH SDIO WILL FOLLOW.

SINCE THE ESSENCE OF THE SDIO MISSION AND GOALS IS INHERENTLY MULTI-DISCIPLINARY, MANY OF THE PROGRAMS MANAGED BY THE SDIO/IS&T OFFICE REFLECT THIS NATURE. RESEARCH CONSORTIA HAVE BEEN ESTABLISHED CONSISTING OF UNIVERSITY, GOVERNMENT LABORATORY, AND INDUSTRIAL RESEARCHERS TO ADDRESS A NUMBER OF THE KEY ISSUES IN THE SDIO PROGRAM PLAN. THESE CONSORTIA MEMBERS BRING A NUMBER OF DIFFERENT SKILLS IN MANY DIFFERENT FIELDS TO BEAR ON IS&T PROBLEMS. AS AN EXAMPLE, IN THE AREA OF SPACE POWER, IS&T HAS SUPPORTED SCIENTISTS SKILLED IN MATERIAL SCIENCES, ELECTRICAL ENGINEERING, CHEMISTRY, AND ELECTRONICS WORKING ON NEW WAYS OF CONDITIONING POWER FOR USE IN HIGH POWER SPACE SYSTEMS. IN SPACE SCIENCE, THERE IS A CONSORTIUM OF SPACE PHYSICISTS, MATERIALS SCIENTISTS, ACCELERATOR PHYSICISTS, ATOMIC PHYSICISTS, AND PARTICLE BEAM RESEARCHERS FROM SEVERAL UNIVERSITIES.

THE INCENTIVES FOR FORMING THE CONSORTIA DESCRIBED ABOVE ARE THE VISIBILITY AND ENHANCED COMPETITIVE STATUS SINCE A CONSORTIUM, IN PRINCIPLE, BRINGS TOGETHER THE BEST TECHNICAL TEAM. IN ADDITION, IT HAS THE ADVANTAGE OF WORKING ON SPONSORED RESEARCH PROGRAMS IN WHICH CLOSE COOPERATION AMONG

INSTITUTIONS IS ENCOURAGED. THE SDIO IS UNIQUE IN THAT THE TRANSITION FROM BASIC RESEARCH TO EXPLORATORY AND ADVANCED DEVELOPMENT IS ACCOMPLISHED WITHIN A SINGLE AGENCY. THUS, THERE IS INCENTIVE FOR INDUSTRIAL RESEARCHERS WHO ARE NATURALLY ATTRACTED TO THE LARGER PROGRAMS ASSOCIATED WITH DEVELOPMENTAL RESEARCH PROGRAMS TO ENTER INTO ACTIVE COLLABORATION WITH ACADEMIC INSTITUTIONS DURING THE BASIC RESEARCH PHASE. THIS WE VIEW AS VERY HEALTHY.

NOW THAT I HAVE DESCRIBED THE MAJOR SDI/UNIVERSITY INVOLVEMENT MECHANISMS, LET ME BRIEFLY SET THE RECORD STRAIGHT ON A COUPLE OF TECHNICALITIES. FIRST, IS&T MONIES AVAILABLE ARE INCLUDED IN A DOD FUNDING CATEGORY LABELED "6.3." NORMALLY 6.3 MONIES ARE NOT USED FOR WHAT THE RESEARCH COMMUNITY CALLS BASIC (UNCLASSIFIED) RESEARCH. HOWEVER, BY DIRECTION OF DR. JAMES IONSON, THE HEAD OF THE IS&T OFFICE, AND WITH THE ENDORSEMENT OF THE DIRECTOR, SDIO, THE IS&T MONIES CONTRACTED TO UNIVERSITIES CAN BE USED AS THOUGH IT WERE FOR FUNDAMENTAL RESEARCH. DR. IONSON'S MEMORANDUM IS INCLUDED AS AN APPENDIX TO THIS TESTIMONY. THIS SHOULD EASE GREATLY THE CONCERN PUT FORTH BY SOME INSTITUTIONS WITH REGARD TO PUBLICATIONS OF THEIR RESEARCH IN THE OPEN LITERATURE.

A SECOND POINT OF CONCERN RAISED BY SOME UNIVERSITY ADMINISTRATORS, WAS, THAT BY ADVERTISING THE AWARDING OF

CONTRACTS TO CONSORTIA OF VARIOUS UNIVERSITY RESEARCHERS, THAT THE SDIO HAD CARELESSLY IMPLIED THAT THE RESPECTIVE UNIVERSITIES THEMSELVES SUPPORTED THE MISSION OF SDIO. I WANT TO STATE CLEARLY, AND FOR THE RECORD, THAT THIS WAS NOT THE INTENT OF THE IS&T OFFICE NOR THE SDIO. WE CONTRACT FOR RESEARCH WORK IN UNIVERSITIES WHERE THE FACULTY HAVE THE ACADEMIC FREEDOM TO PERFORM ANY RESEARCH THEY DESIRE, AS LONG AS IT CONFORMS TO A GIVEN UNIVERSITY'S GUIDELINES THAT INCLUDE SUCH ISSUES AS SAFETY, CLASSIFICATION, AND OF COURSE, QUALITY OF THE RESEARCH PRODUCT. WE DON'T EXPECT NOR WISH TO IMPLY ANY POLITICAL SUPPORT FROM UNIVERSITIES AS INSTITUTIONS. THUS WE WANT TO EMPHASIZE THAT THE IS&T OFFICE HAS ENGAGED SEVERAL CONSORTIA OF UNIVERSITY RESEARCHERS NOT CONSORTIA OF UNIVERSITIES THEMSELVES. IF WE HAVE NOT BEEN CLEAR IN THE PAST, THEN I CAN ASSURE YOU WE WILL BE MORE CLEAR IN THE FUTURE.

SCIENCE AND ENGINEERING INFRASTRUCTURE

IN THE AREA OF THE RELATIONSHIPS OF THE SDIO TO SCIENCE AND ENGINEERING INFRASTRUCTURE, AND PARTICULARLY WITH REGARD TO THE AVAILABILITY OF MANPOWER RESOURCES, I WOULD REFER THE COMMITTEE TO THE TESTIMONY OF COLONEL DONALD I. CARTER, ACTING DEPUTY UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ADVANCED TECHNOLOGY. COLONEL CARTER APPEARED BEFORE YOU ON OCTOBER 2, 1985, AND I BELIEVE DID A VERY COMPLETE JOB OF OUTLINING THE ENTIRE DOD MANPOWER SITUATION. HOWEVER, I DO BRING TO THE COMMITTEE'S ATTENTION THAT THE HOUSE APPROPRIATIONS COMMITTEE TASKED THEIR

OWN INDEPENDENT INVESTIGATION STAFF TO ASSESS THE SDIO MANPOWER RESOURCE REQUIREMENTS. THE REPORT (WHICH IS CLASSIFIED) SHOWED THAT SDIO REQUIREMENTS DO NOT TAX THE AVAILABLE SCIENTIFIC RESOURCES IN THE U.S. EVEN, IN THE MOST AGGRESSIVE OF CIRCUMSTANCES. TO BE SPECIFIC, THE REPORT CITED THE RATIO OF (RESOURCES REQUIRED/RESOURCES AVAILABLE) IN EACH OF THE FOLLOWING AREAS. THESE (UNCLASSIFIED) NUMBERS ARE SHOWN BELOW FOR THE YEAR 1987.

AERONAUTICS & ASTRONAUTICS ENGINEERING	- 3.5%
INDUSTRIAL ENGINEERING	- .5%
CHEMICAL ENGINEERING	- .9%
MATHEMATICS	- .9%
CHEMISTRY	- .2%
MECHANICAL ENGINEERING	- 1%
CIVIL ENGINEERING	- .07%
MATERIALS ENGINEERING	- 4%
COMPUTER SCIENCE	- .6%
OTHER ENGINEERING	- .2%
ELECTRICAL ENGINEERING	- 1.7%
PHYSICIST	-11%

IN A FEW SPECIFIC CASES, SUCH AS OPTICAL SCIENCE, WHERE ONLY TWO UNIVERSITIES IN THE NATION (UNIVERSITY OF ARIZONA AND ROCHESTER UNIVERSITY) PRODUCE PH.D'S, ONE HAS SOME CONCERN. IT IS, HOWEVER, REASONABLE TO ASSUME THAT RESEARCHERS IN

NEIGHBORING DISCIPLINES WILL CROSS-TRAIN AS THE NEED INCREASES. HISTORY HAS CONSISTENTLY PROVEN THIS TO BE THE CASE.

REGULATION DRIVEN RESEARCH

THE SDI PROGRAM IS DRIVEN BY ITS MISSION AND LIMITED BY RESEARCH CAPABILITY AND FUNDING. HOWEVER, SDIO HAS IN THE PAST, AND CONTINUES TO PLAN AND CARRY OUT ITS RESEARCH IN COMPLETE COMPLIANCE WITH THE 1972 ABM TREATY. IN FACT, THE PRESIDENT HAS RECENTLY REEMPHASIZED HIS DESIRE THAT WE USE THE MORE RESTRICTIVE INTERPRETATION OF THE ABM TREATY IN REGARD TO WHAT CONSTITUTES RESEARCH. TREATY COMPLIANT RESEARCH IS WHAT WE ARE COMMITTED TO PERFORM, AND THAT IS EXACTLY WHAT WE ARE DOING.

SDIO AND THE FEDERAL LABORATORIES

FINALLY, A COMMENT OR TWO IS IN ORDER WITH REGARD TO SDIO RELATIONSHIPS WITH THE VARIOUS FEDERAL LABORATORIES. THERE HAS ALWAYS BEEN AND CONTINUES TO BE A NEED FOR NATIONAL LABS TO CARRY ON GOVERNMENT ROLES THAT COMPLEMENT THOSE PLAYED BY INDUSTRY AND UNIVERSITIES. AS RECOMMENDED BY THE FEDERAL LABORATORY REVIEW PANEL IN MAY 1983, WE ARE ASKING THE NATIONAL LABORATORIES TO "PERFORM BASIC AND APPLIED RESEARCH IN AREAS WHERE THE FEDERAL GOVERNMENT HAS A LEGITIMATE RESPONSIBILITY, INCLUDING NUCLEAR ENERGY AND DEVELOPMENT OF MILITARY TECHNOLOGIES AND EQUIPMENT," AS WELL AS "CONDUCT OTHER RESEARCH PROJECTS OF A LONG RANGE NATURE THAT REQUIRE UNIQUE, CAPITAL-INTENSIVE FACILITIES AND MULIPLE DISCIPLINARY APPROACHES."

THIS BRINGS TO A CLOSE MY FORMAL TESTIMONY. I WISH TO AGAIN THANK YOU FOR GIVING ME AN OPPORTUNITY TO APPEAR BEFORE YOU. I HOPE I HAVE GIVEN YOU A NEW UNDERSTANDING OF HOW SDIO IS INNOVATING NOT ONLY IN FINDING NEW TECHNICAL IDEAS, BUT ALSO IN EXPLORING NEW MANAGEMENT MEASURES OF EFFECTIVENESS.

LET ME ADD ONE FINAL STATEMENT THAT APPLIES MORE GENERALLY THAN JUST TO THE ISSUE OF SDI....IN ANY RESEARCH ARENA IT IS ESSENTIAL TO APPROACH THE OVERALL PROGRAM AT ALL TIMES WITH NOT JUST A DEDICATION TO ANSWERING THE QUESTIONS AT HAND BUT ALSO A HEALTHY SKEPTICISM, AS WELL AS WITH CREATIVITY ASSOCIATED WITH THE EXPLORATION OF A NEW FIELD. WITH THE CURRENT PACE OF TECHNOLOGICAL ADVANCEMENT, AND THE STRONG MOTIVATION PROVIDED BY THE HOPE OF A MORE SECURE AND STABLE FUTURE, I BELIEVE THE SDI RESEARCH PROGRAM IS WELL ON ITS WAY.

I WILL BE HAPPY TO ANSWER ANY QUESTIONS YOU MAY HAVE.

FY85 TOTAL SDI FUNDS STATUS

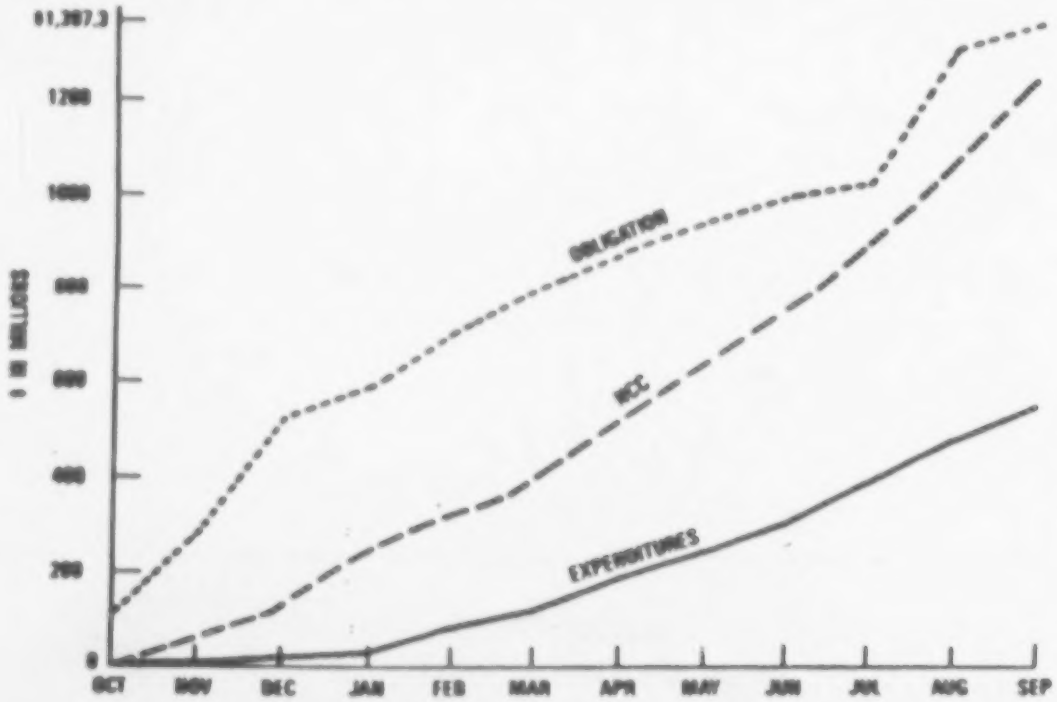


FIGURE 1

STRATEGIC DEFENSE INITIATIVE ORGANIZATION

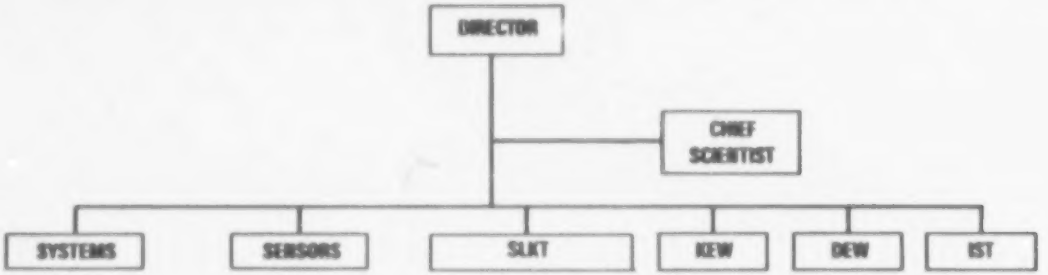


FIGURE 2

OFFICE OF THE SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

8 AUG 1985

SDIO/IST

MEMORANDUM FOR DEPUTY DIRECTOR FOR TECHNOLOGY, DARPA
DEPUTY DIRECTOR OF SCIENCE AND TECHNOLOGY, DNA
STRATEGIC DEFENSE COMMAND PROGRAM MANAGER, OCSA
DIRECTOR, STRATEGIC PROGRAMS, OASN(RE&S)
SPECIAL ASSISTANT FOR SDI, DCS/RDA, HQ USAF

SUBJECT: Reporting the Results of SDIO Sponsored Innovative Science and Technology (IST) Research

The security of the United States depends on an effective defense, of which the Strategic Defense Initiative is a potential future major component. Its ability to cope with future threats depends on how progress is made through Innovative Science and Technology (IST) research. Openness in fundamental research promotes progress toward application of research results.

The conduct and reporting of research performed on university campuses when sponsored by the IST Office of the SDIO, although funded out of budget category 6.3, will be treated as "fundamental research."

Decisions regarding publication of the results of unclassified IST research performed on university campuses will normally be the responsibility of the university author. However, where there is likelihood of disclosing operational capabilities and performance characteristics of planned or developing military systems, or technologies unique and critical to defense programs, the contract will stipulate that the responsibility for the release of information resulting from IST research belongs to the sponsoring office.

OK
Z.aa.

JAMES A. ION SON
Director, Innovative Science and Technology

cc: Director, SDIO
SDIO/SY ATTN: Mr. A. E. Fajans
DUSD(Research and Advanced Technology), OUSDRE
Director, Research and Laboratory Management, OUSDRE
DTSA/TCS

System II
90896

THE WHITE HOUSE

WASHINGTON

September 21, 1985

NATIONAL SECURITY DECISION
DIRECTIVE 189

NATIONAL POLICY ON THE TRANSFER OF SCIENTIFIC, TECHNICAL AND ENGINEERING INFORMATION

I. PURPOSE

This directive establishes national policy for controlling the flow of science, technology, and engineering information produced in federally-funded fundamental research at colleges, universities, and laboratories. Fundamental research is defined as follows:

> "'Fundamental research' means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons."

II. BACKGROUND

The acquisition of advanced technology from the United States by Eastern Bloc nations for the purpose of enhancing their military capabilities poses a significant threat to our national security. Intelligence studies indicate a small but significant target of the Eastern Bloc intelligence gathering effort is science and engineering research performed at universities and federal laboratories. At the same time, our leadership position in science and technology is an essential element in our economic and physical security. The strength of American science requires a research environment conducive to creativity, an environment in which the free exchange of ideas is a vital component.

In 1982, the Department of Defense and National Science Foundation sponsored a National Academy of Sciences study of the need for controls on scientific information. This study was chaired by Dr. Dale Corson, President Emeritus of Cornell University. It concluded that, while there has been a significant transfer of U.S. technology to the Soviet Union, the transfer has occurred through many routes with universities and open scientific communication of fundamental research being a minor contributor. Yet as the emerging government-university-industry partnership in research activities continues to grow, a more significant problem may well develop.

COPY 5 OF 12 COPIES

III. POLICY

It is the policy of this Administration that, to the maximum extent possible, the products of fundamental research remain unrestricted. It is also the policy of this Administration that, where the national security requires control, the mechanism for control of information generated during federally-funded fundamental research in science, technology and engineering at colleges, universities and laboratories is classification. Each federal government agency is responsible for: a) determining whether classification is appropriate prior to the award of a research grant, contract, or cooperative agreement and, if so, controlling the research results through standard classification procedures; b) periodically reviewing all research grants, contracts, or cooperative agreements for potential classification. No restrictions may be placed upon the conduct or reporting of federally-funded fundamental research that has not received national security classification, except as provided in applicable U.S. Statutes.

Ronald Reagan

COPY 5 OF 12 COPIES

DISCUSSION

Mr. FUQUA. Thank you very much.

We have a vote that just came on. Do you have any questions, Mr. Lujan? I am going to come back and ask some.

Mr. LUJAN [acting chairman]. Just very quickly.

The type of management that you have instituted in SDI with central management and then other people pursuing more—would that work pretty well for other programs?

Dr. YONAS. Well, it is not entirely new. The fact of the matter is that the Department of Energy in working with the national laboratories works in that mode with decentralized execution. To a certain extent, DARPA works with that approach.

It is the idea of having a small group that can provide the priorities, the central direction, and basically try to put the day-to-day decisionmaking in the hands of those people that are closer to the problems and to minimize the superstructure in the Washington arena.

Mr. LUJAN. That is a more efficient way as far as you are concerned to work? I thought that the whole program with DOE and the others was put together really to get away from civil service requirements of people not being able to shift around and to fire them or to bring on new hires. I thought that was the primary purpose of it.

Dr. YONAS. This decentralized execution approach, I think, is a useful way to approach this kind of problem.

Mr. LUJAN. As long as I have the floor, we sometimes get the criticism that you just took over other programs and put them under one heading. Is that partly true, totally true?

Dr. YONAS. Some of the people who are involved in that are aware of the fact that what we did was to take the existing programs, the existing budgets, and bring them together under our framework. But then what we did was to restructure those programs according to priorities that were more in the light of the President's directive. In the process, many of the things that were brought into the program now have been changed drastically and are moving off in new directions.

So, I think the program is a very different program than the program that we inherited that existed before the formation of the SDI.

Mr. LUJAN. Most of those programs that you brought in were defense related anyway?

Dr. YONAS. They were certainly related to the SDI mission, but they were structured in ways that didn't have this kind of direct and specific goal orientation.

Mr. LUJAN. What I am getting at is, those programs that you brought in under the umbrella of SDI, were a great number of them considered by researchers, university researchers in particular, as nondefense related? I am trying to get at this whole argument that——

Dr. YONAS. No, these programs really didn't bring in university programs under our wing. What we are trying to do is to create new university programs that didn't exist through this innovative science and technology.

Mr. LUJAN. So, what we hear——

Dr. YONAS. I think we are creating new opportunities for universities to exercise their creativity in attacking these new and very challenging initiatives.

Mr. LUJAN. You have 5 percent as being the university percent.

Dr. YONAS. That was in 1985.

Mr. LUJAN. Didn't we hear yesterday that DOD has about 12 percent?

Dr. YONAS. I don't know. That could be overall.

Mr. LUJAN. Overall, yes, basic.

Dr. YONAS. Yes, I think our basic research is again in the 5-percent range, maybe a bit less than that.

Mr. LUJAN. I am going to go over and catch that vote, and we will be back.

[Short recess taken.]

Mr. FUQUA. I apologize for the interruption, but we had a big matter to take care of over on the floor, that of approving the Journal of yesterday.

Dr. Yonas, are there any current Federal personnel policies that you see that are hampering your organization's ability to recruit competent personnel?

Dr. YONAS. I think it is well known that the Government has a difficult time competing with the private sector in terms of salaries. I am not sure I know what to do about that. It is a fact of life.

Engineering and scientific personnel have a difficult time in terms of competitive salary situations, but the overall Federal restrictions on salary ceilings are a reality.

Mr. FUQUA. Most of the people that are working in your organization, you are not doing—I gather from the figures you gave us—you are not doing any research in-house? Most of it is contracted out, 75 percent to industry, 20 percent to the Federal labs, and 5 percent to the universities, I believe.

Dr. YONAS. Right. There is no SDI house. There is no SDI laboratory or institution in which we could pursue research independently.

Mr. FUQUA. How do you choose which organization receives funding? Do you have an in-house or peer review process? How are those projects evaluated to determine how you get the best science or best research?

Dr. YONAS. The review process has many different forms. I mentioned in the Innovative Science and Technology Program—or I may not have mentioned in my oral testimony—that the program is managed—the hands-on management is carried out by research agencies within the Services and that the management is carried out by Government scientific and engineering personnel within these agencies or within the DOD laboratories. In that case, the management decisions in terms of deciding who is funded are made primarily by those Government personnel. They do not carry out a peer review process. They occasionally go out to other agencies such as NASA or DOE to again use Government personnel for that review process.

Within the other program elements—and some of these program elements involve fairly large programs—what we normally do is advertise. We advertise and request proposals. These proposals are

then reviewed by panels of Government officials. Depending on the size and the nature of the procurement, it could be a fairly extensive review process.

Mr. FUQUA. When you say you advertise, is that like in Commerce Business Daily?

Dr. YONAS. Commerce Business Daily. After proposals are received and we go through a governmental review process, we award contracts to, in some cases, multiple bidders and, in some cases, a single bidder.

So, for most of our contracts, it is a fairly typical process of advertising and receiving proposals and proposal review and then award.

Mr. FUQUA. You had a breakdown of manpower requirements. What disciplines do you generally support in your organization or does it generally follow this on page—oh, there is not a page number.

Dr. YONAS. Yes. That listing is the listing from the House Appropriations Committee special investigative group that looked at the manpower requirements. What they in fact found out is that this program touches every discipline. We are not interested in biological sciences, but basically this really touches all the areas of science and engineering that are current and covers such an enormously wide range that we are relying on practically all aspects of the technical community.

Mr. FUQUA. This generally based on the manpower needs would say that you have 11 percent for physics and 1 percent for electrical engineering. Would that about break down as to how your—in other words, physics would probably be the largest area that you——

Dr. YONAS. No. That reflects the fraction of the available resource. That was the estimate of that committee. It says that of the available resource out there, we will need that portion of that in fiscal year 1987, but in terms of the actual break down, in terms of our own relationship within that, that would be a different set of numbers, and I don't have that.

Mr. FUQUA. I realize that, but I mean would it mean that physics would probably be the highest area rather than something like—you have almost 1 percent for mathematics. That is an 11 to 1 ratio. Your major emphasis would probably be in physics, I imagine.

Dr. YONAS. Well, it is certainly true that physics is an important aspect of our program, but engineering, advanced engineering disciplines and materials research, electronics, computer hardware and computer software—and there are many cross disciplines at this point which are the result of the combination of science and engineering disciplines. For instance, optics, advanced optical techniques involve at this time nonlinear processes, not just the classical optics approaches but require the involvement of everything from atomic physics to electronics.

Mr. FUQUA. You referred to Dr. Ionson's memorandum which stated that university research on SDIO topics funded through the Office of Innovative Science and Technology will not be classified. My question is what legal authority does Dr. Ionson or SDIO have

to make such a claim? If you do, is it just consistent with the National Security Directive 189 of September of this year?

Dr. YONAS. I think within the SDIO, the Director, General Abrahamson, has the ultimate authority to decide how to distribute funds and how to define areas of research. It is my impression—I am not an expert legal authority in regard to this kind of program—but it is my impression that General Abrahamson has the authority to make that kind of determination as long as it is consistent with other statutes. In fact, it is our determination that it is consistent with the National Security Directive which defines fundamental research and defines how fundamental research will be managed.

Mr. FUQUA. Mr. Brown?

Mr. BROWN. Mr. Chairman, I don't have any questions at this time. I am certainly glad Dr. Yonas can be here with us today.

Mr. FUQUA. Thank you very much, Dr. Yonas. We appreciate your being with us.

Dr. YONAS. Thank you.

Mr. FUQUA. Our next witness will be Dr. Robert S. Cooper. He is the former Director of the Defense Advanced Research Projects Agency and now in private enterprise with Pollard Road Inc.

It is good to have you with us.

[A biographical sketch of Dr. Cooper follows:]

DR. ROBERT S. COOPER

Dr. Cooper is President, Chief Executive Officer and Chairman of the Board of Directors of Pollard Road Incorporated. PRI is a new startup company devoted to serving the defense electronics market. Its products and services will span the spectrum of defense needs in surveillance and countermeasures and employ advanced technology in the areas of electronics, electrooptics, advanced computers, signal processing and artificial intelligence applications.

From 1981 to 1985, Dr. Cooper was Assistant Secretary of Defense for Research and Technology and simultaneously held the position of Director of the Defense Advanced Research Projects Agency. As Assistant Secretary, he was the principal advisor to the Secretary of Defense on the allocation of Department resources to research, exploratory development and advanced development projects. He has established Defense policies, program priorities and directed actions of the Army, Navy, Air Force and Defense Agencies to assure future technical preeminence of U.S. weapon systems.

In his role as Director of DARPA, Dr. Cooper directed the technical activities of one of the foremost advanced research and the development organizations in the world. Under his direction during the past four years, the Agency has produced major accomplishments and started new R&D programs in such diverse areas as strategic defense, advanced aeronautical systems, gallium arsenide microelectronic circuits, advanced surveillance sensors, terminal homing sensors, and new generation computing technology employing artificial intelligence concepts. DARPA under Dr. Cooper's direction had a strong influence on the Nation's technical future through leveraged investments in promising high risk, high payoff research projects. DARPA's total annual expenditures are at the $800 million level.

Prior to joining the senior Defense research management team under Secretary Weinberger in 1981, Dr. Cooper was Engineering Vice President of Satellite Business Systems. In this firm, he was responsible for the development, integration, installation and testing of an advanced spread spectrum digital communication satellite system which was completed and brought to initial operation serving the first three customers within three years.

Prior to joining SBS, Dr. Cooper held a variety of R&D management and engineering staff positions. Among these were Director, NASA Goddard Space Flight Center, Assistant Director of Defense Research and Staff Member, Group Leader, and Division Director at MIT's Lincoln Laboratory.

Dr. Cooper holds a Doctor of Science degree from the Massachusetts Institute of Technology in Electrical Engineering and Mathematics.

STATEMENT OF DR. ROBERT S. COOPER, PRESIDENT, POLLARD ROAD INC., ARLINGTON, VA; AND FORMER ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND TECHNOLOGY, AND DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, U.S. DEPARTMENT OF DEFENSE

Dr. COOPER. Thank you very much. I am pleased to be here to discuss this very important issue with the committee.

I would like to submit my formal statement for the record and——

Mr. FUQUA. Yes, we will permit that, and if you wish to summarize, it will be fine.

Dr. COOPER. During the past 4 years, I have been involved, as you pointed out, as the Director of Defense Advanced Research Projects Agency, but I have also held the position of Assistant Secretary of Defense for Research and Technology which placed me in the highest councils of the Defense Department in the setting of research policy. I would like to share with you some of the views that I have come to hold over these last four years on some important issues.

Your committee is considering research and development in the United States and without closely scrutinizing what the Defense Department does in this area, you certainly would have a very restricted picture of what is going on because the Government today funds about 50 percent of the research and development activities in the United States with the industry carrying the preponderance of the rest of that burden. Of the 50 percent in the Government, 60 percent of that total resides in the Defense Department. So, Defense is essentially a preponderant funder of R&D in the United States. Therefore, any policies that are set within the Department of Defense certainly have ramifications into almost every part of our society.

I have had an unusual opportunity during my career to look at this relationship between Government and the scientific and engineering community from just about every imaginable aspect. I have been in the academic community for quite a number of years. I was associated with the Defense Department in the early 1970's. I was Director of one of NASA's large space flight centers for a number of years, and I have been in private business and been back again into the Government and in on some of the most important decisions that have been made for defense research over the past few years.

Over that period of time, I have formed some very strong opinions about some of the problems in relationships that exist particularly between the Defense Department and the scientific and engineering community.

When you are looking at R&D policy, you are really looking at a very nebulous and diffuse thing. Most of the people who come to Washington believe that they are setting policy. Congress certainly believes that it does. Folks in the White House do. Congressional staff think that they really are the ones who set policy in the country on every issue and science and engineering are no exception.

So, it is really hard to find out who the people are who actually set Government science policy. The conventional wisdom, of course, in this city, is that as far as policy setting goes, it is done essential-

ly by those people who disburse funds, those people who have the Government's money in their control and can lay it on the line. They characterize that as the golden rule, that is, he who has the gold rules.

I think there is a misapprehension on the part of most people in power in the city that policy really is the disbursement of the funds, but there are many, many issues with regard to setting policies that are much more important than the money in determining what is happening over the coming decades in the science business. I would like to, in the balance of my discussion here, focus some attention on some of those issues which I think are very important.

In order to put things in context as far as defense is concerned, defense R&D expenditures in the President's request and what the Congress has before it now in the 1986 budget year represents about $31.5 billion. Of that $31.5 billion for R&D, very little of it is for R and lots of it is for D. In particular, two-thirds of those funds lie in accounts that are essentially doing engineering design and development of systems. There is little research per se that is funded by those moneys. In particular, they have little impact on the research community which is interested more in basic and applied research at the fundamental level.

However, one-third of those moneys lie in three accounts which you should focus your attention on and which are important. They are the so-called basic research account, the exploratory development account, and then another piece of a third account called advanced technology demonstration. In Defense parlance, those are 6.3a funds to be distinguished from 6.3b funds.

The total of those three accounts is about $9 billion in the President's request for 1986, and some substantial fraction of that $9 billion actually impacts the research community in our universities, in our industrial laboratories, in the Federal laboratories, and in small business.

It is hard to say exactly how much because there is no fine line of demarcation between basic research and fundamental applied research and the more development activities that follow, but for purposes of categorization, the Defense Department places that line at 6.3a, and the 6.3a funds are really meant to be transition funds that allow us to take both basic and applied research activities that are maturing and to place them into a position where an engineer could actually engineer something that could be useful to society using the basic and applied research results.

With those categorizations, it is my feeling that probably Defense spends about half of the total funds that the Government spends on research that impacts basic and applied activities up through the technology transition phase. This is true for all of the mission agencies, for Defense, for Energy, for NASA, for all of those that have both basic and applied research activities ongoing.

As far as setting policies in the Defense Department goes, of course, the Secretary of Defense is authoritative on that, but he has a principal advisor, the Under Secretary for Research and Engineering who has a great deal of influence on that process. The R&E Under Secretary relies on a number of other people. Recently, this new position that I held over the last 4 years of Assistant Secretary for R&T was created to oversee the activities in those three

accounts and to help both the Under Secretary and the Secretary of Defense make decisions about how those funds would be spent, and what some of the other policies were that were set in the Defense Department in order to help guide the management and disbursement of those funds or the execution of the research programs funded by those monies.

On the other hand, there are many other people who play in that game, the Assistant Secretaries for R&D and Acquisition in the military departments, the military chiefs of R&D. There are a number of folks on the R&E staff who help support the Under Secretary. Of course, the comptroller and the program analysis folks in that office also have a great influence on the Secretary about setting such policies.

So, it really is hard to tell how the policies get set. As a matter of fact, it is my experience over the past 4 years that essentially policies are set by the strong interpersonal relationships that exist among those high level officials. Issues are brought up. They are decided. Various people take various positions on them, and then they interact strongly at both the management and the personal level until a consensus is formed and then the Secretary is given advice. He acts on that advice when there is a decision memorandum in front of him, and he depends on his personal relations with these people in order to decide what the final policies will be.

That process is one that is highly personal. It probably is not amenable to any substantial change. It is a matter of style with the individual Secretary and the way he operates. It has changed many times throughout the years as the various administrations and Secretaries have changed. I have seen that process now since the 1960's in four or five different administrations, both from close at hand and from afar. I can say that it works pretty well or it has worked pretty well in almost all of those settings.

There are some things which have been happening over the years which are trends which are strongly affecting Defense's ability to prosecute research in a way that is beneficial to the United States. I would like to turn now to four key issues and just mention briefly some of the problems associated with Defense research activities.

Those four issues deal, interestingly enough, not so much with the content of research or the programs or the people particularly at high levels who are making decisions, but they deal with more mundane things such as research contracting regulations and the effect that it is having on our ability to get research done; personnel policies which you have brought up in previous questioning; internal management practices which have slowly grown up over the years and seem to be immutably moving in the direction of less and less flexibility, more rigidity and less ability to make reasonable decisions; and, finally, the whole issue of information security regulations or policies which are having a very chilling effect now on our relations with the scientific and engineering community.

First, research contracting. What is the problem? Well, the problem is that the attitude that the Congress has taken and the attitude that the Defense Department has taken toward contract research and contracting in general has resulted in an increasing mountain of laws and regulations which prevent the easy connec-

tion between people in Government and people in the scientific and engineering community to set research projects in motion, to get them moving, and to get the research done.

It is my view that this problem now ranks as the number one deterrent to getting our dollar's worth out of defense research moneys that are expended in the basic and applied research areas. It is an aggravation both to the program managers in the Defense Department and to the researchers themselves, and it is causing a great deal of consternation in both camps and a good deal of ill will and animosity between the two groups.

Let me say that viewing that from the perspective of the 1960's when I first got into the research business after having graduated from MIT, I can say that was not the case in the early 1960's. There was a very close relationship between people in Government and people in the research and development community, and they were able to work together both before, during, and after the contracting process. We were able to get an enormous amount done during that period of time. The other mission agencies such as NASA and, at that time, the Atomic Energy Commission and others also benefited from this free association and relationship between Government managers and scientific researchers.

More and more, the Defense Department and the Government in general has placed the procurement restrictions that we like to place on the acquisition of large systems to ensure the procurement integrity onto the relationship between an individual research worker, say, in a university or in an industrial scientific laboratory and his Government counterpart with whom he is trying to do business and to make decisions. That process really has been a very immutable process down through the years, and it has come to the point now where it can take as long as 1 year to get a research worker under contract even after a Government worker and a research worker have agreed on what the research should be, and there is an enormous amount of paperwork burden on both sides. Lost effort in the Government; lost effort on the research project, wasted money essentially.

Personnel policy. Well, all of the mission agencies now suffer from the fact that the individual managers in the organizations that manage Government research are of increasingly inferior quality as time wears on. This fact is due to the fact it is very difficult to both get into the Government to help the Government out for a short period of time and get out.

It is probably most important to the mission agencies that they have access to the scientific community, to bring them into the Government for short periods of time and to get them out. The reason for that is the reason that you were getting at in your discussions with Dr. Yonas. That is that the decisions on what research gets done and who does it are really the policy issues that make for quality science in the United States.

That process is different in the mission agencies than it is in the National Science Foundation and the National Institutes of Health. In those organizations, the workers in Government are mainly paper shufflers. They sit and wait for the research proposals to come in. They shuffle them into piles, and then they shuffle them out to peer review groups who are really the research workers

themselves, and they ask for them to grade them and to send them back and tell them which ones to fund. When they come back, they organize the ones that are funded in one pile and the ones that are not funded in another pile. They go into the wastebasket. The ones that are funded go to the contracting organization and the contracts or the grants are set, and the process is complete.

There is some but probably not a great deal of insight that needs to be put into the system by the people in Government. It is all regulated by the scientific community itself.

We attempt to emulate that process in some way in the mission agencies, particularly in NASA in the scientific parts of NASA. However, by and large, the decisions on who does the research and what research gets done are decisions that are taken by people in Government. In order to ensure that that process is a quality process, the people have to be quality people.

Currently, the Government is not competing for quality people, and it has no way to compete for quality people with our current personnel policies. In my paper, I have made a number of suggestions as to what I believe needs to be done in order to fix that problem so that we can begin to get quality people back into Government to make the essential decisions.

Management practices. Basic research and exploratory development in defense are processes of discovery, that is, research projects are started on speculation and we don't know really where they are going to go. As the research continues, new things come up. New opportunities arise, opportunities to increase the activity in a particular area to take advantage of an opportunity or to perhaps change direction. Those opportunities all require discretionary funds.

The Congress' attitude about discretionary research funds, that is, setting aside reserves that can be used during the budget year to be able to pounce on opportunities and to move research in the right direction has increasingly been one of not allowing such things. Also, the management in the mission agencies has responded to that by both not allowing their individual managers to hold back reserves for taking advantage of tactical situations during the budget year and searching for the places where they tried to hide such funds so that that can be done.

So, increasingly, I have found over the past 4 years in looking at the way defense research funds are managed in all of the military departments and the defense agencies that there is less and less and less flexibility to take advantage of opportunities in research and that more and more and more of the programming, planning, and budgeting cycle which now lasts at least 3 years—that is, you are both considering the current year, the next budget year, and the budget year beyond that—that funds tend to get locked up or locked into what may be low payoff of diminishing return areas rather than being available for rapid change.

I think we need to change that process. In my paper, I have made a number of suggestions which I think should be implemented.

Principal among those suggestions is a suggestion on the issue of the 6.3a funds, the transition funds which are set aside in defense to try to transition technology from the laboratory into our sys-

tems. It is my belief that the United States today is going through a crisis of transition of technology, not only in defense but in our industries as well. We are noncompetitive in many areas of research and development because of the fact that we haven't paid attention to the process of technology transition.

How do you determine, how do you set aside resources for, how do you focus both management's attention and research workers' attention on this whole process of transition?

The fact is you can't if you don't try, and we don't. The Japanese, the Germans, the Soviet Union do focus attention on that. They do try, and, increasingly, they are beating our pants off not only in the defense sector but in the commercial developments as well. I think we just have to pay more attention to that.

A trend that has occurred in defense is a trend that started in the late 1960's when the 6.3a account was set up. This is the technology transition account, and it has a substantial amount of money in it. It is upwards of $1 billion today. It was meant to demonstrate technology on some grand scale, to aggregate technologies, and to make leaps forward by building experimental aircraft, building experimental tanks, building experimental accelerators or experimental satellites that have the newest technology in them. They are not meant to be a prototype of any weapons system or any other useful system but only to bring the maturity of the technology up to where it could be used in an engineering design of some system or some concept in the future.

That account was set aside for that. Initially, it was used for that. As a matter of fact, the F-16 fighter plane came out of that funding account, and the concept of a technology transition or experimental platform. So did such concepts as the hydrofoil and the air cushion ship vehicles. Some of those didn't pan out and were never used on any substantial scale, but the F-16 is an example of how that kind of paying attention to transition of technology can really pay off.

But quickly the bureaucracy over in Defense found these funds and began using them for a number of purposes for which they were not meant. Those funds today by and large now are used to support very small and insignificant, in my view, research projects mainly to support the defense laboratories.

The account is also used as a slush fund to fund overruns in 6.3b which are the beginnings, prototypes, of engineering developments or system developments. That is very nice, because being in the 6.3 account, you can move funds through that 6.3a/6.3b barrier without the Congress seeing you do it and even without the senior management, particularly the Assistant Secretary for Research and Technology seeing you do it in the Defense Department.

To counter that, the Under Secretary for Research and Engineering in the Carter administration, Bill Perry, began to set aside funds in the Defense Advanced Research Projects Agency for significant technology transition projects. In particular, the Stealth technology that the country now is developing and is moving into systems very rapidly was developed because that technology was transitioned using DARPA funds on a substantial scale.

There are many other examples now of programs that DARPA has that are technology transition programs, and DARPA has es-

sentially taken on the burden in the Defense Department of trying to develop leap-frog capability and to demonstrate it at large scale. It is a process or a task that DARPA was not intended to do, but they are doing it by default.

That is why my recommendation is that we set up in the Defense Department—and I have been working for that over the last 4 years to essentially no avail—an organization whose specific responsibility is to use the 6.3a funds to fund experimental vehicles and techniques at a substantial scale to transition technology out of our research laboratories and into our systems.

Finally, there have been proposals in the Secretary's staff over the last few years which have had a very chilling effect on our relations with the scientific community. These are proposals to have prior review of scientific and engineering results funded in our basic research programs before publication.

It is true that we do have a serious problem protecting technical information and products in defense from our adversaries, particularly since they have stepped up their activity over the past few years enormously to try to get scientific and engineering results and products out of the United States and to use them in developments of weapons systems in the Warsaw Pact nations.

On the other hand, I believe that our tones have been too strident in defense. I believe it is time for us now to project a sense of reasonableness and compromise on this issue to the research community, and to try to draw them into the interpretation of what the national interest really is in the national security sector and to bring them into the process of determining what facts should be protected, what information should be protected, and what products should be protected, and exactly how to do that and not violate the principles of the free flow of information in basic research and applied research at the fundamental level. It is very important to maintain that principle, by the way, because it is that principle, I believe, which is the strength of that entire area.

I just wanted to end on a note. DARPA, the Defense Advanced Research Projects Agency, is a unique organization, and I have really been honored to be associated with it over the past 4 years, and I left it and the Secretary's office with mixed emotions for that reason. DARPA was created at the time the Sputnik was launched by the Soviet Union, and it was set up in order to keep the Defense Department and the Nation at the forefront of technology.

I think that the concept of DARPA is perfect. It is a small organization, a scant 150 people. It has a budget of near $1 billion. It is dynamic. It is close to the Secretary. There is no question about where the authority and responsibility for the decisions about what to do with that research money lies; it lies directly with the Director. There is approval that comes from the Secretary's office, but, by and large, he is very liberal and does concentrate the authority and responsibility for decisions there.

Consequently, DARPA has been able to make contributions in every decade that are at the highest level. We would not have a strategic defense program today if it hadn't been for the development of the technologies that are in that area in DARPA over the last 10 years. We would not have and would not be competitive in the world community in computer science and computer technolo-

gy, probably not even in microelectronics technology if it hadn't been for research accomplished at DARPA. Certainly, in the national security area, such developments as stealth technology, surveillance technology which guards our national interest in many, many ways clearly would not be where they are today without DARPA.

But I must say that DARPA is beginning to suffer even though it is so closely connected to the Secretary and has had an ability to cut through the bureaucratic redtape in the past. It is having a great deal of difficulty right now from the issues that I brought up before.

The contracting issues are making it almost impossible for DARPA to maintain its contacts with the scientific and engineering community as it has in the past. These contract barriers are artificial. They are things that we have created for ourselves. We can ensure the integrity of the research contracting process without putting in year delays and all of the consternation and frustration that goes along with all of the paper that is generated in that process.

We are an information society. We are electronic. Why can't we eliminate the paper completely and go to computer communications with the scientific community completely? DARPA has set the stage for that by creating ARPANET, and we do communicate with the scientific community. There is no reason why we can't do our business in that way as well.

DARPA has an enormous reputation in the scientific community, a very strong reputation for quality research management in Government, and we have been able to attract into DARPA some of the best and finest scientific and engineering people available. But in the last 5 years, I have had a continuing difficult time bringing high quality people into DARPA.

One of the other reasons why DARPA is so great is that it is not an institution. It supports no institutions. It has about 80 to 90 scientists and engineers on the staff, and those turn over at the rate of 25 percent a year. That is, the whole organization changes every 4 years. So, its vitality is assured.

There is no corporate memory at DARPA. Beyond 7 or 8 years, no one even remembers what DARPA did. There is no one there who was there at that time. Consequently, it gets revitalized.

If we stop that revitalization process by making it impossible to bring young, dynamic, and the best scientific and engineering minds into that organization, then it will no longer be able to serve the national interest the way it has in the past. I really think we must do something about that. It is a serious problem.

Also, the relationship with the scientific community is one based on trust and mutual respect. Certainly, a recognition of the external threat that DARPA was intended to counter with its advanced technology, the scientific community has respected that down through the years. To place undue restrictions on the flow of scientific information generated in DARPA programs when it is not needed but to ensure that it does occur when it is needed is a process that we have always been able to manage by personal relations with the scientific community. These recent proposals to make restrictions on the scientific community have even begun to affect

the relationship between DARPA and the scientific community which has always been very good.

I appreciate the opportunity to come and talk to you about some of these issues. I would be willing to answer any questions you have either about DARPA, about the setting of science policy as I see it in the Defense Department, or any other aspects of the research community and government relationship that I can help you on.

[The prepared statement of Dr. Cooper follows:]

BEFORE THE

SCIENCE POLICY TASK FORCE

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE & TECHNOLOGY

CHAIRMAN, HONORABLE DON FUQUA

STATEMENT

BY

DR. ROBERT S. COOPER

PRESIDENT, POLLARD ROAD, INC.

FORMERLY:

ASST. SEC. OF DEFENSE AND

DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

OCTOBER 23, 1985

Mr. Chairman, I am pleased to appear before this committee to give you my views on Defense basic and applied research policies. I agree with the aims of this Committee and those of the Science Policy Task Force to better understand the rationale and mechanisms for federal support of research. Since the federal government funds nearly 50% of all R&D in the United States and the Defense Department's share of that support comprises over 60% of the government total, Defense policies in the R&D sector have a powerful influence on the direction of science and technology in this country. Because it is the nature of the results of research that they impact every facet of this complex technological society, Defense research not only impacts our national security but has ramifications for the nation's overall economic well-being as well. Therefore, without a full review of Defense research policies you would have only a partial picture of the forces which shape R&D in the U.S. and will affect the future of each of its citizens.

My entire career has been spent in research and development during my years on the faculty at M.I.T., my tenure at M.I.T. Lincoln Laboratory, my tour on the Research and Engineering staff in the Pentagon, my years as Director of NASA's Goddard Space-flight Center, my industrial experience as Engineering Vice President at Satellite Business Systems and recently as Assistant Secretary of Defense and Director of DARPA. I have been privileged to work with some of the finest scientific and engineering minds in the Nation, and I have viewed the changing relationship

of the technical community with its government mentors from every aspect. Because of these experiences I have formed strong opinions about how the government interacts with the research community; what is right with the relationship; what is wrong with it and how to fix the problems. I would like to share some of these opinions with you, focussing particularly on the Defense Department.

Defense Research Policy Formulation

Government R&D policy is not a single "entity" but is rather a complex aggregation of law, regulations, practices and individual decisions created by literally thousands of people mainly inside of government. Understanding who these people are and how they influence the research policy-making process is a truly daunting task. Defense research policy is no exception.

Government's attitude toward research is certainly set by the President and the White House science policy infrastructure. However, the Congress, the administrators of the major funding agencies such as NSF, Energy Department, Defense Department and NASA all play major roles. Even personnel policies set by the Office of Personnel Management are very influential in the outcome of government attitudes toward research. I will say more about this later.

Conventional wisdom in Washington is that policy is actually set by those who disburse research funds at the working level.

In my view this belief is erroneous because many other factors have an equal or even greater influence on research directions. However, on this basis Defense would be the most influential determiner of basic and applied research policy in government. This is true even when one discounts the engineering development funds related to specific weapon system developments which cannot really be classified as either basic research or applied research. Instead, those funds, which comprise two-thirds of the Defense R&D budget, should be thought of as applied to equipment design. Nevertheless, the FY86 Defense budget request for funds in the Basic Research, Exploratory Development and Advanced Technology Demonstration accounts total $8.986 Billion. This total probably equals the sum of all other comparable federal investments in basic and applied research exclusive of Health and Human Services (National Institutes of Health).

Persons who are most influential in determining how these funds are allocated and expended are the Secretary of Defense and his principal staff advisor on R&D who is the Undersecretary of Defense for Research and Engineering. In recent years a new position was created on the Secretary's staff specifically to provide additional oversight and advice to the Secretary on fund allocations to these three accounts. That position was designated Assistant Secretary of Defense for Research and Technology. Others in the Department who have some influence on both funding and other factors influencing the direction of Defense research are the civilian Assistant Secretaries for R&D

in the military departments, the military R&D chiefs, the heads of certain of the Defense Agencies, the Director of the Strategic Defense Initiative Organization and more recently certain members of the Defense Security staff. Program Analysis and the Comptroller play a major role in attempting to curb the apparently insatiable appetite for funds of the basic and applied research programs.

By and large the process by which Defense research funding policy is set and carried out is a function of the complex interpersonal dynamics of this relatively small group of people and their advisors.

Key Defense Research Policy Issues

Despite the misconception that funding is the principal means of setting research policy, there are four policy issues which today are much more important and limiting on Defense in realizing its long term research objectives than funding.

In order of importance they are:

1. Research Contracting Regulations
2. Personnel policies
3. Internal management practices, and
4. Information security policies.

Research Contracting

Resent changes to government procurement laws and the resulting Federal Acquisition Regulations (FAR) as well as the corresponding Defense Acquisition Regulations (DAR) have made contracting for Basic Research and Exploratory Development with both universities and private firms into a nightmare. This problem now ranks as the number one deterrent to efficient and timely development of new and innovative research efforts applied to Defense problems. It is a prime aggravation both to government program managers and to researchers and is creating consternation and ill will between them.

The prime factors are 1) procurement leadtimes, which have grown from about 90 days on average to as much as 285 days from research proposal submission to contract signing, and 2) the exorbitant amount of paperwork required for proposal submission and reporting of research progress as well as the arms-length relationship which is imposed on the parties involved. These detrimental factors result mainly from an insistence by the Congress and by Defense acquisition management that research contracting be subjected to the same formalized process by which major weapon systems and general military supplies are procured. That formal process was constructed to insure procurement integrity and competition in contracting. It does not recognize the special nature of research contracting nor the need both for

brevity in the process and a close communication between technical management in the government and the research worker before, during and after the contracting process. If there were only one aspect of Defense research which I could change to improve it, it would be to change the rules by which research contracts are secured. I believe the following steps are appropriate:

1. Change the laws and regulations controlling Defense research contracting. Give it a special status and recognize its special needs.

2. Reduce procurement lead times to 90 days maximum for contracts less than $2M and 150 days for those between $2M and $10M.

3. Accept abbreviated proposals and minimize required "boiler plate" appendixes to both proposals and contracts governing small scale research ((($2M).

4. Accept the concept of "competition of ideas" as satisfying the government-wide goal of providing competition in contracting. Do not require, as a management practice, that any fixed percentage of research contracts be "competed" in the formal sense of the word but instead recognize the processes by which

unsolicited proposals and sole source awards are made as legitimately satisfying the "competition" requirement.

5. Simplify the reporting requirements for basic research, and

6. Streamline financial audit procedures for small businesses and universities as they relate to basic research and exploratory development contracts.

Personnel Policy

The government, particularly Defense, needs competent, experienced, bench level, middle management level and senior scientists and engineers to help manage its research business. Short term, 3 to 4 years, non-career appointments of highly competent people to key government jobs should be made easy to accomplish. Current personnel policies make special arrangements of this sort virtually impossible. Moreover the financial sacrifices required of individuals with highly marketable scientific and engineering skills to serve, even for these short periods, are completely unreasonable. We should take the following steps to fix this problem.

1. Set up a special, limited term, government employment policy for scientists and engineers (similar to but more liberal than the old PL-313 status).

2. Set up a compensation plan for these appointments which substantially matches their civilian compensation. Perhaps this could be done through contracts with their parent organizations.

3. Delegate selection and other decision making relating to the terms and conditions for these appointments to line management. Give them flexibility to compete for the best and finest. Relegate the Personnel Management bure&ucracy to a support role in these special categories of hiring.

4. Limit the leadtime for this type of hiring to a maximum of 3 months.

5. Liberalize the conflict of interest statutes in relation to these special employees.

A personnel policy of this sort would do more to upgrade the quality of Defense laboratories than any other single action the government could take.

The reason why this issue is so important for Defense is that virtually all research is arranged by contract and the selection of individual research workers to carry out the contract research work is made by government scientist and engineers. The quality of the product is entirely dependent on the selection process and without technically competent government personnel to administer this process, there is little chance of achieving a quality product. We must find better ways to attract the best and brightest people from the research community into government for short (3 to 4 year) tours of duty.

Management Practices

Basic research and exploratory development are processes of discovery. To be successful, discretionary resources must be available during the budget year to make possible an increase of tempo or a change in direction as new discoveries are made. The cumbersome process of programming, planning and budgeting which is now uniformly applied across all R&D is inappropriate for more basic research. Also, the long approval chain required by the military departments for program changes and the management systems intolerance of opportunity reserves within the budget must be changed. The following changes in management practices would help:

1. Further decentralize the management of research funds making the offices of scientific research in the

military departments less dependent on headquarters staff for detailed approvals.

2. Consider setting up small highly capable technical management organizations for the Advanced Technology Demonstration (6.3A) accounts in each service.

3. Set a goal of 10% opportunity reserve in the research and exploratory development accounts at the beginning of the budget year and protect these reserves from raids by headquarters staff throughout the year.

4. Further streamline the programming, planning and budgeting approval process for research and exploratory development programs.

Of course these measures can be successful only if the scientific quality of the personnel in the field organizations administering the funds is significantly improved.

Information Security

Defense has a serious problem protecting technical information and technical products it provides for itself in the R&D program from being acquired illegally by the Nations' enemies. This is particularly true in the light of recent increased and organized efforts by the Warsaw Pact nations to

target specific high technology products in this country for illegal acquisition. Proposals by the Security Policy staff in the Secretary of Defense's office to require prior review of research results before publication have had an extremely chilling effect on relations between the scientific community and Defense.

Although the concerns for security are legitimate and require stepped up measures for protection, means must be found to protect the Nation's interests while accommodating the free flow of basic research and most exploratory development information. To set the research community at ease, I believe that, as a minimum, we should:

1. Reaffirm the current policy of exempting all basic research results from prior approval.

2. Return the responsibility for detailed review of exploratory development results to the Research and Engineering staff.

3. Delegate review of exploratory development results with broad guidelines to technical program monitors in the field and involve the R&E staff on an exception basis.

4. Project a sense of reasonableness and compromise on this issue to the research community while sensitizing

them to the need for them to become involved in interpreting and protecting the national interest in this area.

Defense Advanced Research Projects Agency (DARPA)

DARPA is a unique and valuable asset to the Defense Department and this country. It was created by Public Law at the time the Soviet Union orbited Sputnik as was NASA. Its charter is to pursue high risk but high payoff research projects which will keep the Nation at the technological forefront into the indefinite future. It counts among its accomplishments many of the most important technical advances made by this country in each decade since its creation. Its success has been in large measure due to the extremely high quality and dedicated technologists who have served on its staff and the autonomy and flexibility afforded by its special relationship with the White House, the Secretary of Defense, the Congress and the research community. I am proud to have been associated with DARPA as its Director over the past four years.

However, I must report to you and the rest of Congress that the problems I have outlined above for Defense Research are beginning to have a marked effect on DARPA's ability to continue its proud history of accomplishment. DARPA's vitality is maintained by turning over its technical staff every three to four years. Even though its scientific and engineering reputation remains high,

the "personal sacrifice" issue is clearly beginning to reduce DARPA's ability to attract "star quality" men and women to manage its research programs. Moreover, the regressive contracting rules and procedures now being applied to DARPA procurements are limiting its ability to maintain close and friendly relations with the scientific community. I suspect that the other mission agencies are suffering similar problems.

Both the Congress and the Executive branch should move quickly to resolve these problems so that DARPA may continue its great contributions to the Nations technical and national security interests.

DISCUSSION

Mr. FUQUA. Thank you very much, Bob.

How does the DOD determine what basic research is relevant to its mission?

Dr. COOPER. Again, that pretty much is done on a program and individual basis. As you know, the Defense Department's basic research programs and its early exploratory development programs are largely funded out of the scientific research offices.

The Office of Naval Research has been the largest of those fund sources. The policies that are set by the Director of Naval Research and by the staff and the research management in both the civilian and the military part of the Navy R&D structure determine what the important problems are for the Navy and where major investments are to be made.

But, by and large, the Director of Naval Research, in his job as head of the ONR, is able to pick out the particular topics of interest and to give direction to his staff as to where the important topics to be funded would be.

It is no different in DARPA. The Director of DARPA essentially sets the directions for the agency. The office directors, and the program managers follow that and seek and try to draw from the scientific community research proposals that will address the major issues that are defined.

In order to ensure that those directions are connected to the needs of the operational military commands, there are strong connections between the scientific infrastructure in the military departments and the operational elements of that at the senior management level—personal contact, by and large, but many formal contacts as well—at the middle management level where programs are actually worked on, and at the program manager level where research is really funded and monitored.

Almost all research of consequence in the Defense Department is done on contract outside, either in universities, in scientific laboratories in our industry, or in private companies of one sort or the other. A very small amount of the basic research activities now really resides in our defense laboratories. Those laboratories, by and large, are used to help monitor ongoing development activity and to provide scientific and technical bases for making decisions on procurements of various kinds.

The laboratories are, in my judgment, in sad shape for that reason, that it is even more difficult to draw high-quality technical people into those organizations which have down through the years been affected by the personnel policies and by the change in mission. There is not enough engineering and scientific research activity going on in the laboratories to really interest and draw in the high quality people. Consequently, I believe the quality of the advice that is going to our equipment procurers is not of the highest caliber from the defense laboratories.

Mr. FUQUA. You suggested in your statement that there be some policy for short-term appointment of scientists to DOD labs paid at a rate equivalent to their private sector salaries. Would you think that should apply more broadly than just to DOD, say, to NASA and some of the others?

Dr. COOPER. Yes, sir; I do. I believe that would be an excellent technique to try to reestablish the quality of our scientific and engineering expertise in Government, that is, to create what I am sure will be looked upon by the Office of Management and Budget a scientific elite within the Federal Establishment, short-term appointments with perhaps even a restriction that those appointments not be extended beyond the term for which they were initially provided.

Mr. FUQUA. Would not this add to the same problem you were talking about at DARPA where you have turnover, you have no residual company memory, as you referred to it I think, or institutional memory?

Dr. COOPER. I count that as a major plus. I believe that the lack of vitality——

Mr. FUQUA. That doesn't apply to Congress, now.

[Laughter.]

Dr. COOPER. I think the voters and the people who set up the Constitution provided for the tenure of our elected officials.

But I do believe that in research, particularly—it may not be true in legislation—but in research particularly, it is very important to get turnover, that is, to bring in new thoughts and ideas and minds into the process. That is why the institutionalization of laboratories per se, the national labs which have been studied to death over the last few years, the NASA laboratories—I was a manager, director, of a NASA laboratory, and I can see the problems. It is difficult to bring the young people in and to encourage the older people who probably should move on to other endeavors to move out. It is very difficult to do that.

We need to set up a process to do that. That is why DARPA has been so successful. It has no laboratories. There are no institutions that it supports. It has a policy of 4 years max. If somebody comes in and wants to stay beyond 4 years, there has to be a very good reason to do it. I think the vitality that that puts into an organization is essential in the research and development enterprise.

Mr. FUQUA. Before I call on Mr. Lujan, we are very honored this morning to have one of our fellow parliamentarians from Switzerland who also I think was the first woman to serve as a cabinet member in that government, the Honorable Lillian Uchtenhagen. Well, I guess she has stepped out for a moment.

Mr. Lujan?

Mr. LUJAN. Thank you, Mr. Chairman.

I only have one question. Looking over the testimony, you have given about 17 different recommendations of things that should be done. With the exception of personnel, this 3-year contract, and the contracting regulations, most of those 17 recommendations are in fact regulations rather than laws.

Dr. COOPER. That is true.

Mr. LUJAN. Is there any effort to move them within the Department rather than changing laws?

Dr. COOPER. Yes; there have been attempts over the past several years to, I would say, ameliorate the onset of many of these regulations. But you have to realize that many of the regulations and management practices that we have are responses and reactions both to the Congress and to public opinion.

What the Defense Department is doing to itself in the contracting area now with the creation of competition advocacies and very long processes of review upon review upon review of every single thing, seeking out waste, fraud, and abuse are all reactions to congressional criticism and public opinion which is being heaped upon the Defense Department at an enormous rate, probably mostly undeserved. So, the system reacts. It overreacts, so the tendency to inflict wounds upon ourselves in these processes is very great.

I think what we need is moderation in this process and a recognition, perhaps, that the defense research business is different from the procurement of aircraft carriers and toilet paper. It must be viewed differently and accomplished differently. The whole process of managing it should be different from the process of managing the MX project or something of that sort.

In other words, we don't take realistic attitudes. We tend not to have management experts in the Defense Establishment. The short-term political appointees—the quality of those hasn't been all that great in recent years. Their management experience is not great.

I had a great deal of difficulty when I was there finding anyone who knew anything about science and engineering in the Defense Department aside from myself. The problem is that we are not able to draw those people in at the senior level either, for obvious reasons.

How many people do you know who are in the prime of their scientific and engineering career who would be willing to take a factor of three cut in their salary, come into the Defense Department, and stay even for a couple of years and take all of the nonsense that goes with these terrible management practices that go on there? Well, there aren't many these days. There used to be many more.

Mr. LUJAN. But when you say a cut by a factor of three, you are talking about the heads of industry taking that kind of cut, not the average guy who is working for Hughes or one of the—do I dare mention more companies?

Dr. COOPER. Let me give you an example. The Under Secretary has been seeking a new Director of DARPA since I indicated to the Secretary that I would probably be leaving, and that was last November. He has been seeking one ever since, essentially, both—before Don Hicks came, the Secretary and the Deputy Secretary staff were looking for a new Director of DARPA. Since Don came, he has been seeking a new Director of DARPA.

A typical Director of DARPA is, I would say, a man in his mid-forties. He is at a mid- to high-level position in industry, perhaps head of a laboratory somewhere. His salary and fringe benefits may range from $120,000 to $210,000 a year. He comes into the Director of DARPA position and he has to settle for $70,000. Now, that is two to three times salary cut if he is at the high end of that. The Director of DARPA is a high level position in the Defense Department, but it is not an Under Secretary. It is not an Assistant Secretary of Defense. It is sort of middle level management position in a sense.

Mr. LUJAN. On the other side of that, you have people within the Department move up. You have many people in the national laboratories that don't—and I am not seeking an argument in this——

Let me ask you about the set-aside. You call it a 10-percent opportunity reserve. We have that in the national laboratories, perhaps not at the 10 percent level. I just assumed that we had it all over so if some opportunity comes up you can take a look at it and see where it comes out—but we don't?

Dr. COOPER. Typically, there are not adequate reserves in our basic research and exploratory development accounts to flexibly meet the opportunities that are there.

Mr. LUJAN. There are some, though.

Dr. COOPER. There are some, but by and large they tend to result from both planning changes that result from exigencies of one sort or another, plans that one made that just can't be accomplished and so the funds become available for some reason. They are not planned funds. Or from a conscious attempt on someone's part to try to set up such arrangements so that the contingency will be there.

The fact of setting aside a contingency account and making it known to the general management of the Defense Department, if one does that, it disappears. Or if one lets the Congress know that is happening, it disappears.

Mr. LUJAN. Ten percent would be $4 billion in the case of the Department of Defense.

Dr. COOPER. That is true.

Mr. LUJAN. You think that kind of money is needed?

Dr. COOPER. I think that there are $4 billion worth of opportunities in a $30 billion budget that occur every year.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Brown?

Mr. BROWN. Dr. Cooper, I find your testimony extremely helpful and enlightening. I regret that the search is on to replace you. I doubt if it will produce anyone with your background.

Tell me, first of all, this administration has recognized the importance of more flexibility in personnel procedures as have most administrations, and it has been evidenced by such things as developing a more flexible supergrade work force. For example, in the upper levels, it is now possible—I forget what they call this elite group, but they can be transferred around.

Dr. COOPER. Senior Executive Service.

Mr. BROWN. Senior Executive group, and I presume that that reflects a desire to achieve some of the kinds of flexibility that you are talking about for the scientific community.

Dr. COOPER. Typically, I think the Senior Executive Service was set up to create a career individual who intended to come into Government, stay there, and to make Government service his life's work.

Mr. BROWN. All right. I see that distinction, but we have several categories here. We have the Exempt service, the political appointees who can be moved in and out at the discretion of the Executive. Then we have the career executive group that can be moved around but whose career presumably is protected. You are suggesting the need for an elite scientific group that basically would be

short-termers but who could move in and out of Government in pursuit of their scientific career and make their contribution.

Is there any reason in principle that this would not represent a continuation of this same philosophy of enhancing the effectiveness of Government as long as it could be suitably limited to prevent abuses? That is the reason we have these bureaucratic regulations, you know.

Dr. COOPER. I understand.

Mr. BROWN. It seems to me, philosophically, that what you are suggesting is quite compatible with the concept of a flexible, highly qualified group of people available to serve the Government with more or less flexible compensation procedures. Actually, the move which I understand is taking place now to decentralize personnel management from OPM back to the agencies moves in that direction and would give the Department of Defense, for example, as well as other departments, some at least more flexibility in developing systems that would meet that.

Is that your understanding?

Dr. COOPER. Yes, sir. That is my understanding, and I think that is a move in the right direction.

I should point out that such a flexible short-term scientific elite category was established in the 1960's by law. It was called a Public Law 313 appointment. When I first came into the Government in 1972 it was as a Public Law 313, and it took a total of 6 weeks for me to decide to do that, to move my family down to Washington, and to start working.

Currently, in order to move into an SES position, it may take 9 months to maybe 1 year and a half from the time you close with the person and he agrees to do it before you can get him into the Government. That is not flexibility.

Mr. BROWN. What is the reason for that? Is it due to the sheer bureaucratic growth of the Government?

Dr. COOPER. No, I believe there are some potentially good reasons for it. For instance, if the person comes into Government with the intent of making Government a career, it behooves the Government to make absolutely certain that this is the person they want and that he is well qualified and that he has all of the qualities needed for the job and for other potential jobs that he may have to hold in the future. So, the system moves with great caution.

Of course, all of that is centralized in OPM, so all of the approvals must go all the way through the Defense Department which has enough layers to make most layer cakes look trivial. Then, it has to move over across the river where there seems to be some kind of a time warp right at the Potomac. So, the whole process just takes a great deal of time.

There is no reason to do that in the case of short-term scientific appointments where the need is for highly qualified people to manage research programs for a short period of time with the understanding that they will leave after 3 or 4 years.

Mr. BROWN. You have indicated in response to a question from the chairman that the same need exists in other agencies which have a strong research and development responsibility. So, in a sense, if we were to consider the possibility of doing this for DOD, you would set up an invidious situation in which the other depart-

ments, say, Energy or NASA, would say, well, we have the same needs. Why can't we have a government-wide system subject to certain controls to maintain parity and equity that would operate for all the departments?

Of course, that is what this task force is looking at, Government-wide improvements in the management of science and research that would help us to achieve more effectively the goals that we are seeking.

Dr. COOPER. My experience with other organizations, NASA, Energy, National Science Foundation, is that they would also benefit from such flexibility.

Mr. BROWN. Yes, as long as it was carefully defined, I presume. You have pointed to the fact that even in NSF, a lot of the people that they use, and they use short-termers there——

Dr. COOPER. Yes.

Mr. BROWN. But they use them for what you described as paper shuffling, I think.

Dr. COOPER. Yes.

Mr. BROWN. And not for the kind of creative research management that you think the Department of Defense needs.

Dr. COOPER. That is right. And I think the National Science Foundation could benefit from higher quality short-term appointments. I believe that Eric Bloch has had a lot of success in bringing new people into the organization and increasing the quality of the management there. But I think that if you gave him the kind of flexibility that I am talking about that he could even do better.

Mr. BROWN. I would have to investigate this, but I think they have that particular category now where they bring in people from the universities for a 3- or 4-year term or whatever it is, and then they go back to the universities. I don't understand the specific rules and regulations, but if they can do it, surely the Defense Department could do it given the necessary flexibility in pay.

You want to attract, I think, people with a greater research management capability. They are looking for people who have the capability of handling peer review processes.

Dr. COOPER. Yes. I believe you are correct. There is a process in the Government called the Intergovernmental Personnel Act which does allow——

Mr. FUQUA. Rotators.

Mr. BROWN. Yes, they are called rotators.

Dr. COOPER. Yes, and it makes it easy to get people out of universities into Government for a short period of time under certain restrictions and constraints. The problem is that many of the scientists and engineers whom the Defense Department needs probably must come from the defense industry and are not eligible for this.

Mr. BROWN. And their pay scales are considerably higher. Of course, they don't have the side benefits that come from tenured university positions.

It seems to me—you have looked back at the golden age, I think, that you described in the sixties. The situation you are describing as desireable is one which we actually had much more. I recall the Office of Naval Research seemed to have had much more flexibility in dealing with management of their research projects, both in the

nature of the projects and the nature of the contracts that they executed.

Is that true?

Dr. COOPER. That is true. And the laws and regulations since the sixties which have been slowly accumulating and have caused the defense acquisition regulations to be a pile about that tall have really put a damper on that process. And the internal management practices have changed immutably toward less and less flexibility.

Mr. BROWN. Let me ask you this. You have come recently before entering this position from a position with SBS. Is that right?

Dr. COOPER. That is correct.

Mr. BROWN. Would you compare the nature of the arrangements that you had in SBS with what you find in Defense Department? Did they have some of the degrees of flexibility that you are recommending here in that organization?

Dr. COOPER. Absolutely. As a matter of fact, I would compare the situation at SBS with the situation at DARPA 10 years ago. DARPA has a great deal of flexibility compared to any other defense research organization or any other research organization in Government. It is a unique capability. Its board of directors, essentially, is the Under Secretary, the Secretary of Defense, and the Dep Sec Def, three people. The great power and authority that is vested in the Director of DARPA makes it possible for him to move quickly.

At SBS, we had three partners, Comsat Corp., IBM, and Aetna Life & Casualty. Each one of those had a board member. So, there were three guys. They came every month or couple of months, every quarter, to view what the company was doing. The president had great power and authority to do what he thought was right in that business within his business plan. The vice president for engineering had complete authority to do anything, change anything, in the system that was being developed there in order to meet the goals and objectives of the business plan.

Almost exactly the same situation that DARPA is in or was in 10 years ago. Contracting ability—I could make any contracts I wanted to on the outside. They had to be within the laws of the United States, but I had a great deal of flexibility. I could deal directly with the people with whom I was contracting. I could take them to lunch and we could discuss business over lunch.

Mr. BROWN. Three martinis?

Dr. COOPER. Martinis or no, business could be done in that way, very close relationships, and it worked well and we developed an entire communication satellite system in about 3½ years, built three of the first satellites, put two of them in orbit, set up the first three customers with ground stations, built a satellite control facility, and controlled those satellites all in about 3½ years.

Now, the capability there is about comparable to what the Defense Department wants to buy in Milstar. It is about the same complexity of a problem. I would suspect it will take 15 years for the Defense Department to built a Milstar system and get it up there and get it operating and get some of its first customers under service.

The question is, why is that? It is because no one is in charge of that process and everyone is. That is a serious problem for the De-

fense Department. We find ourselves unable to concentrate the power and authority to move in individuals and hold them responsible for making it happen and then giving them the resources they need to do it and checking them from time to time, not every day or every hour and every minute and not with the entire Federal bureaucracy, but with people who should have that responsibility.

If we could just find ways to do that, we could buy systems at 30 cents on the dollar to what we are paying now, and we would get them in 3 to 4 years rather than in 13 to 14 years.

Mr. BROWN. Well, that is impressive testimony, Dr. Cooper. I hope we can make some improvements along that line.

At the risk of throwing a damper on it, I don't think that flexibility made SBS profitable, did it?

Dr. COOPER. Well, the concept of a satellite business system was in itself a flawed concept. The system itself is a marvelous system. The concept of the business that it was to address was a flawed concept, but I think the system now is being used in a different business in ways that are highly profitable.

Mr. BROWN. I really didn't mean that to be an indictment, because we have one of the most effective research systems in the world in our agricultural sector, and it still hasn't made agriculture profitable either, so I don't know what the answer to that particular question is.

Dr. COOPER. I think the business plan is flawed. [Laughter.]

Mr. BROWN. There is something else necessary here.

Mr. Chairman, I won't prolong this, although I have a number of other questions.

Mr. FUQUA. We have two other witnesses.

Mr. BROWN. I know you do.

Mr. FUQUA. We will have to move along.

Mr. Lewis, do you have questions?

Mr. LEWIS. No, thank you, Mr. Chairman.

Mr. FUQUA. Thank you very much, Dr. Cooper, for being here.

Dr. COOPER. Thank you.

PANEL: SCIENCE IN THE DEPARTMENT OF DEFENSE

Mr. FUQUA. In the interest of time, we are going to take our next two witnesses together and then have questions afterwards. Our next witness will be Norm Augustine, executive vice president of Martin Marietta and former chairman and current member of the Defense Science Board. He is also the author of a very interesting book called *Augustine's Laws* and owner of a copyright on a slide rule for baseball managers. Maybe Dick Howser used that last night.

Following Norm Augustine will be Mr. Rodney Nichols, chairman of the American Association for the Advancement of Science Committee on Science, Arms Control and National Security. In addition, in his spare time, he is executive vice president of Rockefeller University.

Mr. Augustine, we would be pleased to hear from you and then from Mr. Nichols.

[A biographical sketch of Mr. Augustine follows:]

NORMAN R. AUGUSTINE

Norman R. Augustine was born July 27, 1935 in Colorado and attended Princeton University where he majored in Aeronautical Engineering and was awarded a BSE, magna cum laude, a MSE, and was elected to Phi Beta Kappa, Tau Beta Pi and Sigma Xi. After graduation he took courses at Columbia University Graduate School of Business and UCLA.

In 1958, he joined what is now the McDonell Douglas Corporation, holding titles of Research Aerodynamicist, Chief Engineer and Program Manager. In 1965 he joined the Federal Government in the Office of the Secretary of Defense, occupying positions including that currently designated as an Assistant Undersecretary of Defense for Research and Engineering. Upon joining the LTV Aerospace Corporation in 1970, he served as Vice President, Advanced Programs and Marketing, for the Vought Missiles and Space Company. Mr. Augustine was nominated by the President and confirmed by the Senate in 1973 as Assistant Secretary of the Army (Research and Development) and in 1975 as Undersecretary of the Army. In 1977, he joined Martin Marietta Corporation where he has served as president of the 20,000 employee Denver Aerospace, senior vice president of the Information Systems group, and is currently executive vice president of the corporation.

He is chairman of the NASA Space Systems and Technology Advisory Committee and has served as president of the 35,000 member American Institute of Aeronautics and Astronautics, president of the 160,000 member Association of the United States Army, chairman of the Aeronautics Panel of the Air Force Scientific Advisory Board, and chairman of the Department of Defense's senior advisory group, the Defense Science Board. He has been elected to the National Academy of Engineering and the International Academy of Astronautics and is a Fellow of the American Astronautical Society, an Honorary Fellow of the American Institute of Aeronautics and Astronautics and a member of the Institute of Electrical and Electronic Engineers. He is a licensed professional engineer in the state of Texas.

Mr. Augustine has served on Boards of Directors of the Colorado National Bank, International Laser Systems, Inc., the American Helicopter Society and the Air Force Academy Foundation, and is a Member of the Corporation of the C.S. Draper Laboratory and the Board of Governors of the Research Triangle Institute. He has been on advisory boards to the Executive Office of the President, the Departments of the Army, Navy, and Air Force, the Department of Defense, the Department of Energy, the Department of Transportation, NASA, the General Accounting Office, the National Academy of Science, and NATO. He is a member of the Board of Regents of the Institute of Cost Analysis, a member of the Board of Advisors of the Society of Logistics Engineers, and a trustee of the Vertical Flight Foundation. He has chaired advisory councils for Princeton University, The American University and the MIT Lincoln Laboratory; has served on advisory boards and boards of visitors ot the University of Colorado, Georgia Tech, Duke, Texas A&M, Florida State, and the Defense Systems Management College and is an Honorary Member of the Faculty of the Industrial College of the Armed Forces. He has been an Associate Editor of the *Defense Systems Management Review* and served on the Editorial Boards of *Astronautics and Aeronautics* magazine and the *Journal of Defense Research*.

He has been awarded the Department of Defense's highest civilian decoration, the Distinguished Service Medal (three awards); the Defense Meritorious Service Medal; the Army Distinguished Service Medal; and the Air Force Exceptional Service Medal. He is a recipient of the American Astronautical Society's Military Astronautics Trophy, the American Defense Preparedness Association's Gold Medal and Knowles Awards, the National Contract Management Association's Roback Award, and is an Honorary Command Sergeant Major of the U.S. Army.

Mr. Augustine has chaired a national committee of the Boy Scouts of America, held adult leadership positions with the YMCA, served on the Board of Directors of Colorado's minority education INROADS, and is a member of the Western Stock Show Association. He is married to the former Margareta Engman of Stockholm, Sweden, and they are the parents of a son, Gregory, and a daughter, René. He is author of the book entitled *Augustine's Laws*, holds a copyright on a slide rule for baseball managers, and is listed in *Who's Who in America*.

STATEMENT OF NORMAN R. AUGUSTINE, SENIOR VICE PRESIDENT, MARTIN MARIETTA CORP., BETHESDA, MD; AND FORMER CHAIRMAN, DEFENSE SCIENCE BOARD, U.S. DEPARTMENT OF DEFENSE

Mr. AUGUSTINE. Thank you, Mr. Chairman and members of the committee. It is a privilege to have this opportunity to appear before you this morning.

With your permission, to save time for questions, I propose I submit my formal statement for the record and summarize extracts of it in about 10 minutes. Would that be acceptable?

Mr. FUQUA. Yes, sir, as long as you assure me it will be shorter than the prepared statement.

Mr. AUGUSTINE. All right.

There are, I believe, four characteristics that help describe science and technology today. They would be that they are big, the pace of change is fast, they are increasingly international in nature, and they are characterized by unpredictability.

One often hears the term big science today, and in the scale of impact, science is indeed big by almost any standard one might have. It has been estimated that over half the scientists who have ever lived are alive as we meet here this morning.

Increasingly, scientific progress has been dependent upon large teams of scientists and engineers working together in complex and costly laboratories. I believe the cost of those laboratories is one of the major reasons why the Government has a significant role to play in supporting science.

I should at this point also say that I am not a scientist personally. I am an engineer, so my comments come from that perspective.

Regarding the pace of change of science and probably more measurably the technology, it has been indicated that the half-life of change of technology ranges on the order from 3 to 10 years for the hard sciences. In the fields of electronics, communications, information systems, and the like, the half-life is probably 2 to 3 years. The pace is suggested, for example, by the fact that the number of lines of code of software extant in the United States today doubles about every 14 months.

Clearly, scientific and technological activity is also becoming much more international in character in recent years. As other countries grow stronger, both economically and in terms of their academic systems, it will be very difficult for the United States to enjoy the kind of a lead it has had in all fields of technology continuing into the future. At the same time, I believe with a degree of selectivity, we can maintain a significant lead in those truly pivotal areas of technology.

I might at this time, picking up on a point of Dr. Cooper's, say that the finest work in the laboratory by scientists usually evidences itself in a form of lead time over the time in which other scientists in other laboratories gain that same information. It is very easy to squander that hard-earned lead in the implementation process, either through mismanagement, bureaucracy, or what have you. I think that is a very important thing for us to keep in mind.

I would also point out that, in my view, science is probably best pursued in an environment of relatively free inquiry unencumbered by rigid schedules and scope constraints. That is not to suggest that science has to be conducted as a large Montessori playground or that it has to be totally chaotic. On the other hand, I think we do have to give our scientists the freedom to explore peripheral opportunities that arise and to exploit the targets of opportunity that they learn of.

I would like to turn now to the impact that various institutions in the sense of mission agencies in the broadest sense might have on the science and technology generation process in the United States. I would like to begin with the largest player in that scene, namely, the Federal Government.

The Federal Government is, in my opinion, and should continue to be a very major factor in the area of scientific research, particularly as a provider of funds for selected applications. I will elaborate on that in a moment.

On the other hand, it is my own belief that the Government should be principally a policy setter and overseer to provide leadership and oversight rather than merely another competitor, although a very large one, to the research capabilities in universities, industry, and other types of institutions. I have found that it is particularly hazardous when the Government seeks to act as both judge and jury in the area of scientific research to decide which projects should be funded when the Government itself is to be a player in carrying out some of those projects.

Turning to the role of the industry, it is with a considerable degree of disappointment that I have to advise the committee it is my belief that industry in the United States cannot, by and large, be counted upon for a major role in performing truly basic research. By that I mean long-term, relatively undirected, relatively high-risk, and often costly research.

The market forces in the United States today disappointingly are such that performance is expected in a period of years, perhaps even quarters. Whereas in Japan they speak of a 25-year plan, a 5-year plan in this country is very difficult to follow, and research just doesn't function on that type of a span.

Happily, there are exceptions to what I have just said, but I think they are that. They are just exceptions.

I would like to mention also the role of the independent research and development program which is so important to industry and permits us to do two things. One, write proposals for new business and, second, to perform research and advance the state of the art. The type of pressures that Dr. Cooper has described are causing us to devote an increasing portion of that money not to the conduct of research but rather to the writing of proposals and the filling out of forms and the paperwork. I think that probably has hurt all of us. That trend is probably hurting all of us.

Turning to academia, my own view would be that our universities probably are a key to the future of scientific research in the United States. At the same time, I would have to say that unlike many of my colleagues with whom I speak, it is my belief that the principal role of the university is to educate rather than to perform research. I happen to believe that many of our universities have

caused that balance to swing too far in the direction of research at the expense of education. I would hasten to emphasize, though, that I believe both are important for a fine university, but I think a degree of balance is required.

I would like to turn to several specific issues that have been raised by this committee. One is the matter of advisory boards. I believe that an enormous amount of expertise has been made available to the Federal Government in the form of advisory committees. I see many of these committees with groups of people that frankly would have been impossible to gather in any other form I can think of simply because the talent level is such and the pressure on their time is such that they are just not available in a single group either to be called upon by an industrial firm or any other element that I can think of.

At the same time, it is becoming increasingly difficult to form advisory committees of that type because of the conflict of interest concerns. I should say that those conflicts can apply to individuals from academia as well as those of us from industry, and that people in academia, particularly in the hard sciences, generally are involved in consulting arrangements and they also have investment portfolios which relate to their field of expertise.

Currently, one must have integrity in the advice being given to the Government. We must have advice without reproach. Unfortunately, I don't have a solution to this concern I raise. On the one hand, I am convinced that one can't legislate integrity. On the other hand, I am convinced that one can't afford to have advisers not motivated by the highest principles.

For whatever it might be worth, I could note to the committee that it has been rare, indeed, that I have ever seen cases where I felt an adviser was acting in other than the best interests of the advised. The reason for that is simple. That is that one's stature as an individual scientist or engineer could not long endure any other type of behavior in the eyes of one's peers.

I would like to briefly give five recommendations to the committee. First is that it is of the utmost importance that scientific research be adequately funded. A major part of the viability of our industrial sector will depend upon that.

Second, we must provide stability. That is difficult to do in changing times with a changing technology, but scientific research is very difficult to turn on and off.

Third, as I mentioned, we must provide our science a good deal of latitude to perform research and pursue opportunities that may arise. We must not overly constrain them with contractual requirements.

Fourth, as with any endeavor I guess, the key to success tends to be the people who are involved. Our Federal Government must have the highest quality people if the Federal Government is to deal with the enormous sums of money that it has to allocate and the major decisions it must make.

Today, it is becoming increasingly difficult to hire that caliber of people in the Federal Government. I see it from the other side from what Dr. Cooper described where I see how easy it is for those of us in industry to compete for talented people with the Federal Government. I think that is a very unfortunate trend for the Nation,

and I would be happy to address that should the committee like to raise any questions.

Finally, I would like to mention the need for organizational latitude in permitting the universities, the research institutes, the industry, and the Government in this country to work together. At the present time, we have somehow managed to create an adversarial situation between many of those that I have just mentioned. We are finding that we can't compete, for example, against Japan where they have successfully brought such groups together.

The antitrust concerns are very real and very appropriate. But there is a degree to which one can carry that which is counterproductive to our ability to compete in the international marketplace. I think we have seen that in our attempts to compete, particularly, with the Japanese who have been so very effective.

I believe that is a good place to stop with a summary of my statement, Mr. Chairman and members of the committee. Again, I thank you for your interest in what I believe to be a very important field, and I appreciate the chance to share my views with you this morning.

[The prepared statement of Mr. Augustine follows:]

STATEMENT OF

NORMAN R. AUGUSTINE

***

COMMITTEE ON SCIENCE AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

***

Washington, D. C.

23 October 1985

Mr. Chairman and members of the Task Force, it is a privilege to have this opportunity to share with you my views on Science Policy and, in particular, the manner in which the mission agencies and federal laboratories relate to that policy.

I feel relatively certain that every witness who has ever appeared before a Congressional hearing has expressed the view that the subject at hand was of transcending importance. Truly, however, this would seem to be the case with regard to the matter of establishing a national Science Policy, for reasons which I will relate shortly. I would, therefore, like briefly to discuss some current trends in science and technology in the United States and to address the role of the various institutional participants in the conduct of science and technology activity. I would then like to close with several recommendations for the betterment of this effort.

It is perhaps appropriate to begin with a few caveats which may be helpful to the Committee in assessing my testimony. First, I myself am not a scientist; I am an engineer. Simply stated, I am not personally active in (although certainly greatly impacted by) the effort to roll back the frontiers of knowledge. Rather, whatever contribution I may have made lies principally in the realm of applying new scientific knowledge, hopefully to the betterment of mankind. Second, the views I will express are solely my own and do not necessarily reflect positions of the various organizations with which I have had the privilege of being associated over the years. Third, my perspective is not the crisp, experienced viewpoint of one who has spent an entire career in a given type of mission agency. Rather, my "biases" reflect a combination of experience I have gained working in large industrial firms, in a university research laboratory, on advisory boards to a number of universities and not-for-profit organizations, serving on the board of directors of small entrepreneurial firms, and of course, in my service in government as well as in an advisory capacity to the government. With that caution that my background is one of breadth rather than depth, I would like to proceed to share with you my views on the subject of a national Science Policy.

First, I know of no pursuit having greater leverage, in terms of its impact on society, other than education itself, than scientific research. A number of the most pressing problems facing the United States and the world today have as at least an element of their solution, scientific and technological advancement. These problems cover a spectrum which includes the creation of jobs to stimulate the economy and restore the trade balance, the continued provision of energy as existing sources dwindle, assuring the peace through strong national defense, providing for the health of our citizenry, and helping assure adequate food supplies for the world.

Four characteristics which help to describe science and technology today are that they are big, their pace of change is fast, they are increasingly international in nature, and finally they are characterized by unpredictability.

One often hears the term "Big Science." Science today, in the sense of both scale and impact, is indeed "big" by almost any definition of the word. It has been estimated that over half of the scientists who have ever lived are alive at the present time. Increasingly, scientific progress is dependent upon large teams of scientists and engineers working together in complex and, unfortunately, costly laboratories. The growing price of facilities is one of the most fundamental factors in making government financial support of science a necessity.

The pace of change of science and, more measurably, technology is indicated in the fact that by almost any measure the half-life of technology is today on the order of three to ten years, depending upon the particular discipline under scrutiny. In the burgeoning area of information technology, for example, which represents the confluence of the fields of computers and communications, the doubling times of capabilities (such as the number of circuit elements on a chip) are measured in terms of a mere two to three years. The magnitude of the information technology explosion is also evidenced by the fact that the number of software lines of code extant in the United States is doubling every fourteen months. Yet, few of the fundamental ingredients which have made all this possible were even contained in the existing body of knowledge a mere three decades ago.

Clearly, scientific and technological activity is also becoming much more international in nature. As other countries build stronger economies and educational systems, it seems inevitable that the U. S. will become less dominant in the overall sense. This does not, however, mean that we cannot or should not maintain important leads in selected, critical areas of science and technology. Further, it is important to note that scientific leadership can be measured in terms of "time" -- usually a matter of a mere few years -- and that in terms of impact, that hard-earned lead can easily be squandered in the process of moving from the laboratory into practice.

Finally, the unpredictability of the effort to advance science and technology is widely recognized. Albeit very frustrating to managers, the impact of this uncertainty is of the utmost importance in creating a national science policy. This property of science has lead, one might note, to the embarrassment of even some of the more capable scientists in the world, not to exclude such giants as Lord Kelvin who assured us that "x-rays are a hoax," or Thomas Edison who is said to have noted that "fooling around with alternating currents is just a waste of time." When seeking to establish a definitive and explicit science policy, it is humbling to realize that penicillin was discovered only when Sir Alexander Fleming happened to observe that bacteria did not grow in a portion of a culture that had been accidentally contaminated by mold, or that synthetic fibers were the result of a researcher's observation while watching a

reaction vessel used in unrelated polymer research. Or that a catalyst critical to the formulation of artificial rubber was found only when a mercury thermometer, being unjudiciously used as a stirring rod, accidentally broke. Or that the search for artificial sweeteners was unexpectedly propelled forward when a researcher working in another field noticed a sweet taste to a cigarette that had been resting on a laboratory bench. Or that William Roentgen discovered x-rays while investigating not x-rays but cathode rays. Examples of this characteristic of science and technology are legion.

The lesson would seem to be that science is best pursued in an environment of relatively free inquiry, unencumbered by rigid schedules and scope constraints. That is not, of course, to suggest that research must be totally chaotic or that all areas of pursuit are equally likely to impact society in an important and favorable manner. It does, however, seem to suggest that research is best performed when given fairly broad latitude in terms of day-to-day conduct, within the bounds of overall areas of focus.

Turning now to the impact which various "institutions" can have on science and technology, perhaps one should begin with the federal government itself. The federal government is, and, in my view, should continue to be, a major provider of funds for scientific research. On the other hand, I believe the government should not itself, in general, be a major conductor of that research. This belief simply stems from my view that in a free enterprise system, government best serves the people when it functions as a provider of very selected resources, leadership and oversight, rather than as merely one more competitor, albeit a large one, in the world of day-to-day operations. My experience has been that particularly in the area of science and technology it is hazardous when the government, even inadvertently, finds itself in a role of being both judge and jury. This can and does occur when, for example, the government must determine whether or not specific projects are to be supported, yet some of the candidate undertakings would be performed by the government itself whereas others would be pursued by outside institutions. A logical question might be why the government should then be called upon to underwrite science and technology at all if the beneficiaries are principally within the free enterprise segment of our economic system. The reasons have to do with the scale, risk, lead time, and the breadth of impact of scientific research.

There are a number of more specific trends within the general area of federal support of science and technology which are potentially significant in the formulation of a science policy. As but one example, in decades past the efforts of the (Defense) Advanced Research Projects Agency were focused upon advancing basic research and applied research. Over the years since its inception, however, the funds allocated to DARPA have been, to an increasing

degree, used for prototype demonstrations -- a very worthwhile undertaking in its own right but nevertheless still a major drain on the basic research resources originally intended at the time ARPA was established. Similarly, in the early aviation program, the NACA was a major factor in building the research base used by the aerospace industry. Today, in the space program, probably of necessity because of the characteristics of that program, this role has reversed and the NASA has become the customer. Hopefully, as the space program matures, we will be able to realize the benefits of NASA's on-going effort to shift much of the "hands-on" part of the space program to non-governmental institutions.

Turning to the role of industry, it is with some regret that I must report my view that, by and large, industry in the U. S. cannot afford to undertake major, fundamental research efforts except in very selected instances. Our market-oriented society, unlike that peculiar to Japan and certain other nations, simply does not permit industry the luxury of pursuing large, long-term, high risk investments. There have, of course, been examples in the past of excellence in research in U. S. industry. The work of the Bell Telephone Laboratory stands out as a shining example, but even that organization, in essence, was a part of a regulated entity as opposed to a true free enterprise institution. I am simply not optimistic that industry itself can be counted upon to fund, on a significant scale, truly basic research. On the other hand, both large established firms and small venture capital firms are certainly effective at applying technology, and it is in this important area that we must be sure to create an environment which can nurture these bodies.

The role of the independent research and development program sponsored by the government to provide discretionary funds for its contractors to pursue research and technological activities is a significant factor in this regard. Unfortunately, its impact is now being diluted through the costs of increased reporting and oversight and, even more importantly, the requirement to devote large portions of the available resources to extensive proposal writing as opposed to the conduct of true research and exploratory development itself.

Turning to academia, my view would be that our universities are a key to the future of scientific research in the United States. At the same time, unlike many of my colleagues, I happen to believe that the primary role of a university is to teach. This is not at all to say that university research is unimportant, only that an appropriate balance of research and teaching needs to be maintained; and in my judgment, in many instances this balance has shifted too far away from teaching.

The establishment of research institutions associated in one of a variety of fashions with universities would seem to me to represent an excellent approach for achieving the balance that I believe is so necessary to both education and to the creation of knowledge. An additional important issue in this regard continues to persist with respect to the role of universities in research pertaining to national defense. Clearly, many of our nation's finest academic institutions have struggled with the propriety of pursuing research relating to military matters, particularly when that research is classified. At the same time, it seems clear that it cannot be in the best interest of the nation to invest major national resources in establishing defense-oriented research programs in universities only to find that these programs are terminated when the universities subsequently readdress their policies in response to concern over specific military events. Long-term positions need to be articulated so that the interests of both the universities and the government may be protected.

I would now like to turn to several specific issues that have been raised by this Committee as a result of its earlier deliberations.

Beginning with the matter of advisory boards, it is my overall belief that an enormous amount of expertise and experience is made available to the government through the forum of advisory boards and is done so at a very, very low cost. I have observed committee after committee made up of groups of individuals of a talent level that simply could not have been assembled in any other form than as an advisory board -- if for no other reason than the competing demands for those individual's time and attention.

However, in order for an advisory board to be effective, it must not only have competent members willing to truly "engage," but it must also have a sponsor who is truly interested in receiving advice. If one or both of these ingredients is not present, the success, or lack thereof, of an advisory board is predetermined. Several important issues still exist with respect to the government's use of advisory boards, the most important of which I believe to be those relating to the matter of possible conflicts of interest. Such potential conflicts, incidentally, can apply to individuals from academia as well as those from industry in that people in academia, particularly in the hard sciences, often have consulting arrangements and investment portfolios which relate to their field of expertise. My experience has been that it is becoming almost untenable to assemble a group which is competent and experienced in a given area, yet which has no connections in that same area which could lead even to a perceived conflict of interest. On the other hand, the integrity of the advice being given to the government must be absolutely without reproach. Unfortunately, I do not have a solution to this problem. I am, on the one hand, convinced that one cannot legislate integrity. I am equally convinced that one cannot afford to have advisors motivated

by other than the highest principals. For whatever it may be worth, I might note that it has been rare, rare indeed, that I have ever seen an advisor acting with what I thought was other than the best interests of the advised. One's stature as an individual scientist or engineer simply could not long endure such behavior. Nonetheless, a much clearer delineation of whatever is to be the government's policy in this regard is badly needed out of fairness to both the advisor and the advised.

A similar conflict arises in terms of the degree to which advisory committee meetings should be held in the public spotlight. Clearly, the public has a right and a need to know what type of advice its government is receiving. On the other hand, the existence of large and sometimes politically inspired audiences can be a severe impediment to the type of candor which is needed if advice is to be very useful. A mechanism affording careful balance in this regard is essential.

Finally, it has been my experience that most advisory committees tend to be reactive -- mainly reviewing inbeing activities rather than taking the lead in suggesting new and promising avenues to be pursued. This is perhaps the major failing of the advisory board process as it exists today.

Turning to the important area of research on behalf of the Department of Defense, important, if for no other reasons than its size and consequence, it is my belief that such research should be performed for the one and only purpose that it contributes to providing for the nation's military security. The argument that such research has peripheral social benefit or that it stimulates the economy, while fortuitous, does not seem relevant in terms of determining fundamental worthiness of support. That is, defense research should be supported to whatever degree is commensurate with the risk one wishes to accept in the area of national security; and beyond that, funds should be diverted directly to other purposes for the explicit pursuit of other benefits.

Research relating to national defense, as well as that associated with commercial endeavors, also poses certain particular problems in the area of dissemination of information. Research thrives in an open environment, with various researchers able to communicate rapidly and freely among one another. At the same time, in some instances, such communications can be harmful to the interests of our nation or even to those of an industrial firm sponsoring the research in question. I reluctantly conclude that industrial firms often must necessarily protect the findings of their research to a very high degree. On the other hand, in the case of basic research underwritten by the government, the nation as a whole may be best served by internationally pooling the information thereby derived, at least if that information is not explicitly vital to national defense. In most, but not all, cases the nation's commercial and military objectives can be accomplished

by erecting barriers to the dissemination of selected information relating to the application of scientific knowledge -- such as manufacturing techniques -- as opposed to seeking to restrain the flow of scientific knowledge itself.

Finally, the Committee has inquired as to what particularly promising areas of scientific exploration exist today. Certainly, the answer to this question deserves a great deal more discussion than is possible here, but in my judgment would certainly have to include bioengineering, nuclear physics, artificial intelligence (both robotics and knowledge-based systems), energy generation, micro-electronics, optics, and materials.

In the way of summary, I would like to offer five recommendations in the form of observations for the Committee's consideration.

First, it is of the utmost importance to the nation's well-being that fundamental scientific research be adequately funded and that a substantial segment of the needed support be provided by the federal government. Grants are a particularly effective form of such support, overseen by the well-established peer review process.

Second, stability must be provided in the research environment. This can perhaps best be accomplished through multi-year grants. Crash programs, such as the Manhattan and Apollo projects, can produce enormously successful and important outcomes, although their price often includes major disruption in human and institutional terms when those projects reach their conclusion.

Third, a great deal of freedom must be afforded scientists performing research to pursue their own approach and follow schedules dictated by the nature of the work itself. In addition, they need to have a degree of latitude to explore promising findings within the bounds of an overall area of concentration. I can assure the Committee from personal experience that it is very, very difficult for a manager to accept such a freewheeling concept. Most of us as managers are much more comfortable with specific objectives, specific schedules, specific budgets, and measurable milestones. Unfortunately, the attempt by the government to impose such a management philosophy on the conduct of research in order to avoid the possibility of occasional failures is, to an increasing extent, having the effect of reducing the possibility of occasional successes.

Fourth, as with most endeavors, the key to quality scientific research is the involvement of competent and motivated people. Our nation has been unnecessarily forgoing the potential contributions of a large number of talented individuals in this regard, as measured by the absence of females in a proportionate sense in the

technological workforce as well as by the difficulty the economically disadvantaged have in obtaining the necessary education to pursue scientific fields. In my judgment, the principal problems in the area of scientific education lie in our nation's high schools and secondary schools, rather than in its universities. It is also my belief that our universities best enhance our nation's scientific strength when they emphasize basic principals rather than areas of current, and often transient, public appeal.

It would not be proper to leave this subject of scientific and technical education without at least mentioning the large, controversial and multi-faceted role that foreign students and faculty play in our nation's graduate schools today, particularly in the area of the hard sciences. This subject is too complex, having important pros as well as cons, to dismiss in a few simple sentences. Let me simply observe that it is a matter worthy of careful thought in formulating a science policy. In the same vein is the matter of remuneration of government employees working in the scientific arena. If we truly believe that people are the key to success of scientific and technological undertakings, it is then false economy indeed for the government to pay inferior salaries and at the same time hope to keep the caliber of personnel needed to make the multi-million dollar decisions faced within government almost daily.

Fifth, there is a need to provide greater organizational latitude to enable our universities, the federal government, and U. S. industry to work together in the pursuit of research and technological activity. The long-standing concern in this nation over anti-trust activities is a real and proper one. At the same time, overly restraining legitimate pursuits because of unfounded anti-trust concerns can be enormously harmful to the interests of the United States in the world marketplace. Japan's activity in this regard is a clear case in point.

In closing, I would like to thank the committee for this opportunity to express my views on these contentious but important topics. I might note that when I had the privilege of serving our country as the Assistant Secretary of the Army for Research and Development, I steadfastly held the position that the adequate support of basic research was the number one priority of the Army's material acquisition program; more important on the margin than even development or production activities. The failure to discover radar, nuclear fission, the transistor, stealth airplanes, or for that matter, the Salk vaccine, could have had a truly decisive impact on our well being. That this committee is willing to dedicate the time to listen to over one hundred fifty witnesses on the subject of science policy is a very encouraging sign indeed to those of us engaged in the field. This may be particularly important when one realizes that a very major portion of the members of the Soviet Politburo and Central Committee are personally trained in the fields of science and technology, yet such backgrounds are relatively uncommon among individuals serving in the U. S. Congress or in the senior ranks of the Administration. Your interest is very much appreciated.

This completes my prepared statement. I would be happy to answer your questions.

Mr. FUQUA. Thank you very much, Norm.
Mr. Nichols?

[A biographical sketch of Mr. Nichols follows:]

RODNEY W. NICHOLS

Rodney W. Nichols, executive vice president of The Rockefeller University, is a specialist in research and development who has served with industrial, governmental, and academic organizations. He is the principal deputy to President Joshua Lederberg in planning and managing activities at the University, a center for research and advanced study in the biomedical and related behavioral and physical sciences.

Mr. Nichols came to the University in 1970 as special assistant to Frederick Seitz, then president, was elected vice president in 1972, and was elected executive vice president in 1978 at the beginning of Dr. Lederberg's administration.

From 1966 to 1970, he served as special assistant for research and technology in the office of the Secretary of Defense, working with the director of defense research and engineering. His principal responsibilities were in coordinating programs and funding for basic and applied science, assessing the relationships among the R & D efforts of various federal agencies, and analyzing issues raised by new Department of Defense systems and policies. Mr. Nichols frequently represented the Department in testimony before Congressional committees. He was awarded the Secretary of Defense Medal for distinguished and meritorious civilian service in 1970.

From 1959 to 1966, he held the post of manager of the Systems Analysis Laboratory of the research division of Melpar, Inc., a Westinghouse subsidiary. Initially working in experimental solid state physics, he was later responsible for the technical direction of an applied research group carrying out laboratory and computer-assisted studies for a variety of federal and other sponsors.

An analyst of the U.S. policies for science and technology, he has participated as a consultant with a number of organizations including: Office of Science and Technology Policy in the Executive Office of the President, Defense Department, State Department, Peace Corps, National Science Foundation, National Institutes of Health, Rand Corporation, General Telephone and Electronics Corporation's Research Laboratories, Georgetown University Center for Strategic and International Studies, Congressional Commission on Governmental Procurement, Library of Congress, Commission on the Operation of the United States Senate, the early 1970's physics survey of the National Academy of Sciences, and Congressional Office of Technology Assessment (OTA).

He has served on the Committee on Science, Engineering and Public Policy of the American Association for the Advancement of Science (AAAS), and presently is chairman of the OTA's Advisory Panel on long-range plans for advanced materials and their applications in manufacturing. He is a member of the High Technology Advisory Council of New York State's Urban Development Corporation.

In the international area Mr. Nichols has been involved in many studies concerned with the application of modern technology for civilian and military purposes. He was a member of the U.S. delegation to a special meeting convened by the United Nations on preparations for negotiations of chemical and biological arms control (Geneva and New York, 1969). Deputy chairman of the U.S. delegation to the U.N. Committee on Science and Technology for Development (New York and Geneva, 1973–78), he then was appointed to the U.S. delegation at the world-wide conference on technology for developing countries (Vienna, 1979). He was named by the U.N. Secretary-General in 1977 to the Advisory Committee for Science and Technology, the senior technical group advising the Economic and Social Council.

He was chairman of the Congressional Office of Technology advisory panel on strategic responses to an extended oil disruption. A member of the advisory committee to the State Department's Bureau on Oceans, Environment, and International Scientific Affairs, he is also chairman of the AAAS Board's Committee on Science, Arms Control, and National Security.

He has served on the Board on Science and Technology for International Development, and on the Board on Committee on Advanced Study in China, for the National Academy of Sciences. He has worked and travelled in Europe, Latin America, the Middle East, the Caribbean, and the People's Republic of China.

He is the coauthor of two books: *Research and Development and the Prospects for International Security* (with Frederick Seitz), published by Crane, Russak, & Co. in 1973, and *U.S. Military R & D Management*, published by Georgetown University in 1973. He also was chairman of a committee supervising the development of the *Verification Challenge: Problems and Promise of Strategic Nuclear Arms Control Verifi-*

cation, R.A. Scribner, T.J. Ralston, W.D. Metz, published under the auspices of AAAS by Birkhauser Boston in 1985.

Mr. Nichols co-chaired and contributed the lead paper to a panel of experts who met in Peru in 1983 and developed a volume entitled *Research and Development Linkages to Production in Developing Countries,* (editor M.P.W. Silveira, published under the auspices of the United Nations by Westview in 1985.

Mr. Nichols has lectured widely before professional groups and at universities including Yale, Columbia, Pennsylvania, Duke, and New York. He has written numerous articles and reviews for such journals as *Science, Minerva, Innovation, American Scientist, Physics Today,* and *Technology in Society,* of which he is a founding member of the editorial board.

Selected as a National Sigma Xi Lecturer for 1974–75, Mr. Nichols examined national trends in research and development. During the summer of 1975 and 1978, he was a featured speaker in two national CBS television series. The lectures covered the impacts and responsibilities of science and technology, and the post-World War II foreign policy developments affecting the scientific community.

Born in Evanston, Illinois on September 15, 1937, Mr. Nichols received an A.B. degree in applied physics from Harvard University and has had graduate training in the physical, biological, and social sciences. He is a member of the American Physical Society, the Council on Foreign Relations, and a Fellow of the American Association for the Advancement of Science. He is also a member of The Cosmos Club in Washington and The Century Association and 7th Regiment Tennis Club in New York.

Mr. Nichols is married to the former Carolyn McKnight, who was born in Louisiana and is a published novelist, senior editor and publishing executive at Bantam Books. They live in New York City with their son, Christopher, who was born in 1976.

STATEMENT OF RODNEY W. NICHOLS, CHAIRMAN, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE [AAAS], COMMITTEE ON SCIENCE, ARMS CONTROL AND NATIONAL SECURITY; AND EXECUTIVE VICE PRESIDENT, ROCKEFELLER UNIVERSITY, NEW YORK, NY

Mr. NICHOLS. Thank you, Mr. Chairman.

In addition to joining my old friend, Norm Augustine, in congratulating the committee, I think that the morning shouldn't go by without somebody mentioning this superb review developed by the committee and staff on science policy issues. That has already become an interesting talking paper around the country in circles you may not have been aware of.

I submitted a prepared statement, Mr. Chairman, and would like to just zip through the statement highlighting a few themes and paraphrasing some of them. I would like to begin on a note that combines both some concepts and a little bit of funding data.

You posed the question of what will be the long-range implications of the reemergence of the Department of Defense as a major sponsor of basic and applied research. I gather that is at least one of the major issues under review this morning.

You have already gotten a good deal of data earlier this month about it, but in my prepared statement I also go back and emphasize the point that in 30 years there has been a dramatic reduction in the Defense Department's role as a sponsor of basic and applied research. It is now down to about 10 or 11 percent of the total Federal effort, as I note on page 3, and I think there is almost no chance that one could imagine this doubling over the next decade.

So, if you put that as an upper bound, we might be talking about as much as 20 percent of the total Federal effort supporting basic and applied research coming from Defense. It is really hard for me to believe that that would be regarded as an unreasonable situa-

tion. Obviously, the Defense Department has to defend its budget and have good projects, but in terms of one way of thinking about long-range implications, it seems to me quantitatively unlikely it will rise nearly to the level that it was 20 or 30 years ago.

Second, Mr. Chairman, in page 4 I review some of the well-known statistics about the total national funding in comparison to total defense R&D funding. I would like to remind you of some data that neither of the earlier two witnesses this morning specializing in defense matters at the moment mentioned. During the boom years, from 1958 roughly to 1972, in constant 1958 prices, defense R&D declined from about $5.7 billion to about $5.5 billion while the rest of the Federal spending tripled in real dollars or almost tripled from around $5 billion to between $13 and $14 billion.

So, this trend is long standing and the reemergence is, in a certain way, a misleading way to label what is, in fact, going on, because there has been a downward trend very steady now for 30 years. What we may see looking back from the year 2000 is that this was a fluctuation in the mideighties that goes back a few percentage points but not really significant in what seems to be a long-term secular trend.

On pages 5 and 6, Mr. Chairman, I try to ask the question that I think you were getting at and a very deep question it is: what will happen to the national technical work force and to the civilian economy more generally as defense R&D rises somewhat, even if it only rises a little as it seems to me to be likely the case?

There is not clear-cut evidence on that. You and the congressional support agencies undoubtedly will gather more than a lonely administrator in the boondocks of Manhattan can gather, but I did look at some of the literature. It looks fairly clinching that there is no real clear-cut sustained competition when it comes to technical manpower. In fact, generally speaking, what has happened in every one of the boom and bust periods over the last 30 years is within just a few years after defense R&D spending rises with only that lag, it creates its own technological manpower.

The signals are given very clearly to the scientific and engineering work force, and more people get into the fields that are being called upon. There is very little evidence from economists who differ very greatly in their political and ideological perspectives when they look at the data, they see very little clear-cut competition.

When it comes to impacts on the civilian economy broadly, clearly you can argue that there are major opportunity costs. I remind the staff and any members who are not familiar with it, there is a very good book written by Murray Weidenbaum in the early seventies about this point—what are the opportunity costs of defense spending generally, and defense R&D spending in particular.

There are clearly some opportunity costs, but again the case is not clinching that you can find specific science policies, to go back to that theme, Mr. Chairman, that could be modified to take account clearly of these civilian impacts.

Let me mention two points which are clear implications, however, about which there is no debate, in my judgment, about the reemergence of DOD. One is that there is going to be more debate

about defense R&D. As we draw more people into this community, and we are seeing that almost every day in the newspapers now—software for SDI being a conspicuous example—there will certainly be more debate. And that absolutely coincides over the last three or four decades with rises and falls in defense spending and other social attitudes, such as the Vietnam era.

A second point is the, I believe, rapidly rising tensions about flows of technical information, a theme that this committee has returned to, happily, from time to time over many years. I would just take a few phrases from the Corson panel report of the National Academy of Sciences:

> The best way to ensure long-term national security lies in a strategy of security by accomplishment. An essential ingredient of technological accomplishment is open and free scientific communication.

There is absolutely no doubt in my mind that as the Pentagon increases its defense R&D, it is going to find it harder to resolve the issues raised by this very seminal observation of the Corson panel, but it is very sound. What we have typically seen and is hinted at rather gently by Drs. Yonas and Cooper is that the technical part of the Pentagon favors this strategy. It is other policy officials in various agencies who don't favor it.

You find, I think, close to unanimity in the R&D community, Mr. Chairman, about this proposition.

In the midpart of my testimony, I run the risk of talking about concepts that members of this committee are likely to know more about than we. One of them is what do we mean by pluralism.

On page 26, Mr. Chairman, of your task force report and beginning on page 9 of my testimony, I take a stab at defining pluralism which has certainly become a cliche. We mostly think we know what it means, and I couldn't find, actually, a very reasonable stab at defining it, so I did try.

One of the points that quickly emerges when you start thinking about pluralism is that we claim that there are strengths in it because it disperses our strengths. That is in contrast in some sense to what Norm just argued. There is some good science in industry, and the question is how much.

On pages 19 and 20 and 21 of my testimony, I tried to collect some data that would answer this question. I agree with you, Mr. Chairman, and your task force agenda that we should try to be more quantitative than hand waving as we have typically been about these policy issues. One question I asked was where do Nobel Prize winners work? That is, where do the U.S. workers who win a Nobel Prize and are employed in the United States work? Some of this doesn't map identically with citizenship.

In that data at the bottom of page 19 through 1982—I apologize that this is 2, approaching 3, years out of date—I take a crack at that. It is interesting because it shows that roughly 10 to 12 percent of Nobel Prizes went to scientists in industry and Government laboratories. That is roughly the same proportion of basic research funding that went to scientists in Government and industry laboratories.

The conclusion I would draw—let us say a hypothesis to be looked at much more carefully—is that if funding continues for

long periods of time, and if it is directed in a way that all of the witnesses this morning have encouraged us to believe is necessary, that is, broad questions, deep questions, and stable funding, there is no reason why industry and Government laboratories can't do Nobel Prize winning caliber work. In fact, they have.

The prizes this year to scientists connected with ONR, one of whom still works there, I think, confirms this trend.

The next two questions I asked were, where do members of the National Academy of Sciences and National Academy of Engineering work? Again, it is not too surprising that members of the Academy tend to be in universities. That is, in fact, the home of basic science.

But it is interesting that again you get about 10 percent of the best scientists in the country as measured by this reasonably reliable indicator are working in industry and Government.

When you look at the NAE, the data change, naturally. Most of the best engineering is in industry, but not all of it by any means. In fact, only about 55 percent of the best engineers work in industry. The rest, who after all are elected by these industrial engineers who control the polling in the NAE, more than 35 percent are in universities and 5 percent or so in Government.

My hypothesis based on this data would be that it is reasonable to believe that you can do first rank science in a Government laboratory. To counter another stereotype, it seems to be reasonable to believe you can get distinguished, practical, innovative engineering out of a campus. Surprise, surprise.

That is the strength of pluralism, Mr. Chairman, I think, and a great power in the American system. To the degree that we further homogenize and classify and over-typify institutions, we will have lost one of the great powerful forces that we have from dispersing these strengths.

A final more conceptual point along that line and one that the committee and staff are well familiar with is the little diagram on page 23 that underscores with this one example from solid state physics, a field I know a little about or used to know, the enormous feeding back between technology and science. It is not correct to think about what this committee is up to in terms of a linear journalistic model of research feeds information which is then tidily taken care of by Norm's engineers and out comes a product with a business plan.

We all know that isn't true. What we don't focus on enough is at the fairly fundamental level the ways in which new tools enable new science, and new science feeds back into the new tools to do technology.

Let me skip, Mr. Chairman, because I know our time is limited to just highlighting two international points. I agree with Mr. Augustine that they are important, and I have mentioned four in my statement. I think at the moment I would really just like to highlight one, the social sciences. On page 28 of my testimony I have just a few paragraphs devoted to a subject that I realize you devoted several days of hearings to, but to my limited knowledge of what you have on your agenda of social sciences, you didn't emphasize this point.

That is the dearth of money and attention to social sciences pertinent to foreign policy and national security and arms control. For about 20 years, we have been running a national experiment with doing no social science research pertinent to foreign policy to the first order. This really originated because of a Defense Department program—one might say gaff or glitch or flap—about the so-called Project Camelot which was some studies beginning in Latin America about the sources of revolutionary movements. There is a book actually been written about this flap which reference I give you.

Since then, it has been almost impossible for DOD to support any basic research, unlike physics or astrophysics or computer software. It can't really touch this field very much. There is a little psychology that goes on in human factors engineering and vigilance before a radar scope, but no social science. The other agencies that clearly need that assistance or, in my view, might benefit from it, say, the State Department, either don't ask for the money or when they ask for it they don't get it.

This is an issue that is underappreciated because, in fact, much of our decisionmaking is not benefiting from the potential for some scholarship that could help it.

Let me close, Mr. Chairman, on one small skeptical note, and that is to doubt whether or not the pace of science and technology is necessarily all it is cracked up to be. In the last few paragraphs on pages 35 and 36 I remind the committee that the tricks, say, of genetic engineering are roughly 30 years old. They have been sharpened a great deal in the last decade by some profoundly new insights, but we first learned that DNA was the genetic material in 1944. Nobody paid much attention; it didn't help medicine and didn't produce biotechnology. It didn't produce boomlets on Wall Street near where I live, but it has been around for quite a while.

The first masers were working very well in the mid-1950's and quickly led to lasers. That whole technology is regarded, in a way correctly, as revolutionary, but it is really not clear that science moves quite as fast as in our more breathless hyperbole we would make it seem.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Nichols follows:]

Prepared Statement by

Rodney W. Nichols
Executive Vice President
The Rockefeller University
New York

before the

Task Force on Science Policy
Hearings on Science in the Mission Agencies
Committee on Science and Technology
U.S. House of Representatives

23 October 1985

Outline

		Page
1.	Introduction	1
2.	Specific Commentary on Chairman Fuqua's Questions	2
	2.1 Reemergence of DoD in Research	2
	2.2 Effects of Mission-Agency Support	7
3.	Advantages and Problems of Pluralism in R&D	9
	3.1 Defining Terms	9
	3.2 Fundamental Premises for Federal Roles	12
	3.3 Historical Pattern of Dispersed Strengths	18
	3.4 Federal Patronage: Fashions and Complexity	24
	3.5 International Trends	27
	* U.S. Trade	
	* Social Sciences and Foreign Policy	
	* Developing Countries	
	* Arms Control	
	3.6 Final Note	32
4.	Brief Responses on SPTF's Statement of Purpose for Hearings on Science in Mission Agencies	33
5.	Concluding Remark	35
6.	References	37

Statement by Rodney W. Nichols before Science Policy Task Force

Committee on Science and Technology

House of Representatives

23 October 1985

1. Introduction

Thank you, Chairman Fuqua, for the honor of being invited to participate in your review of United States science policy. I am pleased to join these hearings entitled "Science in the Mission Agencies and Federal Laboratories" because I have thought and written about this subject from industrial, governmental, and academic perspectives. I also extend my congratulations to you, the Committee, and staff for undertaking such an ambitious inquiry. No matter what the long-term results may be, you have turned a cynical Washington aphorism on its head by raising the visibility of the important, not just the urgent.

Permit me to say a word first about my professional background. After university training in applied physics, I worked for seven years in industry on both civilian and military R&D, then served for almost five years in R&D management within the Office of the Secretary of Defense. For the past fifteen years I have been at The Rockefeller University, a center of basic research which has only a few DoD-sponsored projects. Mr. Chairman, although I have never been a full-time "policy scholar," I have been engaged as an investigator, administrator, and analyst within the domains you now are evaluating.

My testimony is divided into three sections: first, commentary on two questions posed in the September 6 invitation-letter from Chairman Fuqua; second, a more general discussion of the advantages and problems of pluralism in R&D, drawing upon draft material being prepared for a special 1986 issue of the quarterly journal Technology in Society, which will examine the pros and cons of forming a Federal Department of Science and Technology; and third, brief remarks on the areas identified in the Statement of Purpose for the SPTF Hearings during October 1985.

2. Specific Commentary on Chairman Fuqua's Questions

In Mr. Fuqua's 6 September 1985 letter inviting this statement, he asked:

(a) What are the long-range implications of the re-emergence of the Department of Defense as a major sponsor of basic and applied research?

(b) How does mission-agency support, as opposed to science-agency support, for research affect the types of research performed, the payoffs, the justifications of funding, the research performers, and infrastructure?

2.1 Reemergence of DoD in Research

The first question clearly requires an historical perspective. Before highlighting data on this point, however, and then discussing the implications, I should state my basic conclusion: growing DoD support

will be a great asset to the country's R&D institutions, if the process continues to respect the strong U.S. values in research that is high-quality, openly published, and usually investigator-initiated.

You already have received key data on the financial trends covering DoD's support of 6.1 and 6.2 programs. But two points (mentioned, for example, on October 2 by Teich, Carter, and Tegnelia) deserve emphasis. First, the "reemergence" of DoD as a major sponsor must be put into the historical series of the actual amounts and proportions. Defense funding was more than 50% of the total Federal support of research (6.1-type efforts) during the 1950's, dropped to roughly 25% of this total during the 1960's, and fell again to about 10% during the 1970's. It is now about 11% of the total Federal effort. Many significant trends are left out of such a stark summary, such as NASA's surge and NIH's growth. But the facts are clear: as the national R&D waves expanded greatly over the past 30 years, DoD's relative influence declined sharply in research.

Furthermore, it is unlikely that DoD's role would increase over the next decade to become, say, double its present proportion. Reasonable observers may differ on the merits of what was decided in the past, and on the probability or desirability of equally brisk changes over the next decade or two. But it is hardly extreme to devote 10% (even 20%) of our research resources -- and 1% (or 2%) of the DoD budget -- to national security. Indeed, it is a moderate and perhaps cautious approach, given the critical roles of technology in deterrence, intelligence, and arms control.

Second, the fields being supported by DoD are pertinent to long-range defense missions and ripe for advanced work leading to findings that will be broadly useful. Although the available aggregate data about this -- as shown in Teich's Tables 2 and 3 -- are not too clarifying, the

basic point is probably valid at any level of detail. What should be of concern is assuring the quality of work supported in these fields. To the exent that there is growing "micromanagement" from any quarter, often the best investigators will be driven away; this leads naturally to lower quality, and then even to lesser relevance because new "leads" may not be seen and tracked. Accordingly, DoD should be given fair latitude in its choice of fields. I will say a little more on this later from other perspectives.

Let us now extend the exploration of long-range implications by considering the broader national trends.

All of the distinguished "chief scientists" in OSD during the past 25 years have been keenly conscious of the varied interactions between Defense R&D and the national technical effort. Over this period, total military R&D spending has declined as a proportion of the total national R&D spending (from about 75% in 1955 to about 25% today) and it has declined as a proportion of the total national R&D funding to universities (from about 20% in 1960 to about 5% today).(1) Let us recall the "boom years" in R&D: from roughly 1958 to 1972, in constant 1958 prices, Defense R&D actually declined from $5.7 billion to $5.5 billion while all other national R&D (Federal and non-Federal) rose dramatically from $5.2 billion to $13.5 billion.(2)

Such trends are watched carefully in the Pentagon because the vigor of the overall national base is essential for the technological edge that political and military leaders have continued to count upon. The turnaround in these trends during the past few years should renew both the national and the Defense capabilities.

But what about the overall national economy? Did -- and would -- a large DoD role in basic and applied research affect the demand and supply

of scientists and engineers? Did -- and would -- such a "reemergence" of DoD affect the civilian industrial sectors? Unequivocal answers to these questions are not available, to the best of my knowledge. But they are good questions, and there is some evidence.

For technical personnel, the analyses strongly suggest that rising military R&D spending, through the usual market pulls with a lag of a few years, creates its own technological labor force.(3) Apparently there has been little, sustained, clear-cut competition between the defense and civilian sectors.(4) Indeed, for example, one leading national "high technology recruitment index" was 15% lower in March 1985 than in March 1980, confirming that only a few shortages exist now and that the recent 1-2% unemployment rate for engineers (low of 0.7% in 1966-68 and high of 2.9% in 1971) is not an artifact.(5)

As far as the civilian economic impacts of Defense R&D (or of general Defense spending) are concerned, the data I have checked are not convincing. Everyone knows that Defense-linked "high-tech" industries are important, e.g., semiconductors, electronics, telecommunications, computers, special manufacturing materials and robots, information-based services and firms of all kinds.(6) Military spending selectively pushes these and other newer technologies; and it often favors certain younger industries. Just as obvious, in principle, are the "opportunity costs," i.e., allocating public funds and devoting scarce talent to all of DoD's payroll, procurement, and R&D programs.(7) Yet pinning down those theoretical "opportunity costs," and being sure about the results of any reallocations to a major alternative purpose are not easy tasks.

In the overall economy, the military buildup that started in 1978 and extended through 1984 brought military spending from 5% to 6.7% of

the GNP (compared with 13% in 1953, 9% in 1968, and 6-7% in the early 1970's). Although changed tax rates and other trends are clearly important, higher military spending rates apparently account for a third of the size of the presently too high Federal deficit.(8)

Altogether, the plentiful literature on these complex economic subjects sheds little light on specific science policies that would make a large difference in either enhancing benefits, or suppressing difficulties, flowing from the interactions of increased Defense R&D within the general economy.

Before moving to Chairman Fuqua's second question, I want to add two remarks about ostensibly paradoxical tensions that will arise with substantially increased DoD support of basic and applied research.

One is that as more scientists and engineers become involved with the most advanced fields pertinent to defense, we can expect even more vociferous debates about both the R&D itself and the new systems that could be deployed as a result of the R&D. This will emerge naturally, as it did in PSAC and the DSB over past years, because some of the most talented leaders in research will become strong, independent critics of choices already made and of future options favored by the Pentagon.(9) Look at the professional literature of persuasive advocates and scathing skeptics about individual DoD R&D programs and about the economic and political consequences of these technical trends.(10) Look at the membership of policy-oriented groups such as the NAS's CISAC or the AAAS's CSACNS. You find that the most informed debaters have had considerable experience in the Defense R&D community. Yet for about 15 years, as defense funding declined relative to other areas and as the Vietnam era conditioned attitudes, there were comparatively fewer young people coming

into these fields of science pertinent to national security and arms control. With recent trends, the prospects are good for more debate on the R&D elements of decisions in defense policy.(11) Frankly, this is healthy as well as inevitable. But there will be days when the Pentagon may not be so happy.

My second point is that there will be a further increase in the tensions already evident about flows of technical information. I agree strongly with the deceptively simple, profound conclusion of the Corson Panel: "the best way to ensure long-term national security lies in a strategy of security by accomplishment, and an essential ingredient of technological accomplishment is open and free scientific communication."(12) To be sure, there are risks and caveats in such a strategy; and there are rugged problems in implementing it while enforcing our laws on espionage and promoting our trade. But the principle is so sound, so consistent with U.S. character, so fundamental to everything we know about what makes research thrive, that the temptations to "protect" our increased R&D results must be resisted in the future, as they usually have been in the past by the technical leaders in the Pentagon itself. This will be difficult for DoD's relationships with universities -- despite the welcome new funds for fellowships, instruments, and for research -- and yet it has always been a central feature of any "guidelines" for those university relationships.(13)

2.2 Effects of Mission-Agency Support

Mr. Fuqua's second question -- on the specific effects of a typical "mission-agency's" research support vis-a-vis a "science agency's support

-- is more complex. My comment here will be brief, since the next section provides a more complete statement on this matter. Consider this perspective: when a "mission-agency" supports the "R" in R&D and manages it well and coherently, the process inccrporates most of the attributes of "science agency" support that some observers believe are superior to (or at least different from) mission-agency practices in research administration.

Historically, the Defense research agencies (perhaps most notably ONR) have shown the insight, stylie, and patience needed to provide long-term funding for world-class science that pays off. Not every project, of course, was excellent; and not every grant was transparently relevant to Defense.

In DoD's 6.1 and 6.2, the goal was and is to press the limits of knowledge, develop human resources to provide advice on new technical problems seen in the field, and throw fresh perspectives on the full range of long-range options for pursuing old and changing missions.(14) NIH has fulfilled essentially these functions for HEW and HHS; it is doing research with disease and health care goals in clear view. While NSF ordinarily is regarded as the archetype of the "science agency," it also may be viewed as a truly national-mission-agency in most of the practices and results of the conventional mission-agencies. For instance, NSF's new research-oriented engineering initiatives surely keep an eye on U.S. trends in the international marketplace.

In short, when a mission-agency has a shrewd and balanced R&D program, part of that program will be in science. To pursue the science well, the agency and the projects must be in good standing with the scientific world.

3. Advantages and Problems of Pluralism in R&D: Arguments Favoring the Organization of Federal R&D Around Independent Missions

As noted in my introduction, this section draws upon a draft manuscript being prepared for a special 1986 issue of Technology in Society, a quarterly journal, which will be devoted to the pros and cons of proposals to form a Federal Department of Science and Technology. Although today's hearing focuses largely upon the research sponsored by DoD, the SPTF's reviews sweep more broadly and, in any case, the Defense R&D program is best placed in a larger context.

3.1 Defining Terms

Pluralism has become a cliche that points toward a rich texture of ideas, practices, and vested interests. Yet pluralism in U.S. R&D encompasses specific attributes. Sometimes, pluralism means just one part of the following definition and, at other times, the term signals the entire set. A definition might include:

(a) generally, the idea that there are multiple Federal and private sources (or sponsors) of R&D; i.e., several major agencies with large R&D efforts that include in-house technical staffs and laboratories along with outside grants and/or contracts to academic and industrial groups;

(b) more specifically, in most fields, the existence of multiple sponsors at a significant scale of research and development; e.g., NSF, DoD, and DoE sponsoring materials science and engineering; NIH, NSF, and DA supporting molecular genetics and biotechnology; and both DoD and NASA

funding advanced engineering studies of the aerodynamics of new vehicles;

(c) the concept that each Federal agency pursuing its operating missions has an R&D unit carrying out a substantial program of basic work, e.g., Commerce through the NBS, Agriculture through the ARS, HHS through NIH, and Defense through DARPA and the OXR's;

(d) from the standpoint of an investigator, the existence of opportunities to gain truly independent reviews of a novel idea (or of a rejected proposal) so that the decision of one potential sponsor does not eliminate the possibility of another open competition; and

(e) from the standpoint of private, working-level organizations performing R&D, the availability of multiple governmental and private sponsors, e.g., an academic chemistry department receiving industrial funds, state government support, philanthropic aid, along with grants from ACS, NSF, DoD, and NASA; and this notion applies to corporations as well, say Texas Instruments carrying out R&D contracts for DoD as well as pursuing its long-range business goals with their own R&D investments from revenues on sales to commercial customers.

Taken together, these arrangements provide a hedge against fluctuations in the fashions and policies influencing any lines of R&D support. More sharply put, they avoid a "science czar," or an "establishment," controlled by the Federal government.

A full-blown pluralistic system depends upon a high level of sustained R&D. It runs the risks of some redundancy when sponsors overlap their support -- surely at the research end of the spectrum, where there are many, small projects underway through many sponsors. By doing so, it gains the long-run advantages of giving all missions a window on re-

search.

Pluralism also protects against the inherent frailty, even occasional ignorance, of decisions by research managers. It aims, in principle, to strengthen the broad swath of R&D by being aware of how unpredictable are the origins of great ideas; and how unpredictable are the consequences of results that first seem mere curiosities. Thus, some funds go to all good ideas in order to ensure that the few seen later to be the best have had a chance.

The U.S. system of pluralism, the product of a wealthy country with a self-confident approach to science serving national goals, has worked well. It is the envy of the world. Only a combination of strong forces could challenge it. We now see three such forces. First, large Federal deficits tempt both the executive and legislative branches to reexamine "discretionary spending" -- i.e., the programs left after statutory spending such as Social Security -- and R&D is always a large fraction of this "controllable" amount. Moreover, the deficits elicit worries about "potential duplication," always an issue with R&D carried out in a decentralized fashion.

Second, other powerfully industrialized nations challenge our trade by orchestrating their public/private initiatives in R&D with a more centralized style. So the U.S. naturally considers the option of Washington-dominated "industrial policies" that would target R&D.

Finally, the national R&D resource-allocation process recently seems almost too competitive. It involves state and local governments competing for high-technology economic assets; hard-strapped universities struggling for revenues and impatient with a "Matthew Effect" in big-time research ("the rich get richer"); and individual investigators and fields

frustratingly trying to compete for their share of a research pie that grows slowly.

Despite these new strains on the foundations of pluralism, it still functions. And it depends above all on the Federal Government's "model" of how R&D functions in the country.

3.2 Rationale for Federal Roles: Fundamental Premises

The rationale for large Federal investments in science and technology has been remarkably consistent over the post-World War II era. This rationale has been articulated, with little dissent, by leaders in government, industry, and universities.(15) The upshot is that science is so important to the nation that only the Federal government can assure the scale and continuity of funding required for the varied national purposes. Justifications always stop well short of asserting that Uncle Sam should be the primary user of the results of R&D -- except in defense and, until recently, in space. The Federal rationale takes account of the marketplace.

Beginning with Vannevar Bush, this "marketplace" of interest to Federal R&D policymakers is a large notion spanning many elements of the private sector.(16) It must track the supply and demand for technically trained individuals from high school graduates to postdoctoral fellows. It must consider whether, and how, to renew mature industries facing strong international competition. It is always trying to accelerate the pace of technology transfer in order to enable entirely new industries to grow quickly and provide new jobs. It aims to strengthen the scientific

foundations for regulatory decisions serving the public welfare. It tries to apply modern science to prevent and cure diseases while being economical in the uses of known therapies. And on and on. In sorting out these myriad elements, what are the underlying premises of national (not just Federal) R&D?

Elementary premises are hard to "prove." But it is clarifying to state, explain and rationalize them. The three premises formulated here seem to reflect the beliefs of the majority of working scientists and engineers as well as policy-making officials in Washington.

The first premise is that mission-oriented research exists. Terminology gives trouble here immediately because some observers regard this premise as inherently contradictory. Wouldn't strongly mission-oriented work naturally be so applied that it would border on being "development?" If so, it would not be research. Moreover, the idea of "directing" basic research always provokes contention. Yet we also know how difficult it is to characterize excellent research as either "basic" or "applied."

There are many examples of successful mission-oriented research. The situations always became clearer in hindsight. The physical and engineering sciences, in fact, frequently have thrived on a close coupling -- virtually a blend -- of fundamental work and specific applications. More about this later. In the biological and medical sciences, too, the coupling has been close; although modern biomedical scientists are not as used to thinking about the issues involved.

The core of this premise is that the problems involved in achieving a specific long-range mission--from a government agency's point of view, or a corporation's view--sometimes must be expressed in such fundamental

terms that only basic research is likely to solve them. That kind of research is not necessarily less basic, or less pure, than comparably long-range but ostensibly more curiosity-driven scientific efforts.

Mission-oriented research works best when the goal is clear and fairly broad, not fuzzy and narrowly conceived. The time-frame for measuring success ordinarily is long and the sponsor does not insist impatiently on specific results to be achieved at short intervals. Yet the periodic quality-controls on the individuals in research must be authentic, open, and severe. The effort receives stable funding until either the desired results are achieved or new paths are encouraged as more productive.

Often, such research proceeds best at a university. But there are splendid examples of successful mission-oriented basic research in governmental and industrial laboratories. In any case, the Federal government is the only patron with sufficient staying power to fulfill this premise, especially with respect to diverse national goals pursued concurrently.

The second premise is that economic incentives are powerful. This may be evident to any industrial audience. Yet the idea is worth emphasizing in debates about how to organize R&D designed to foster greater innovation and productivity. Market mechanisms can promote, and surely need not degrade, both the quality and pace of the research community. Higher salaries, profits, royalties, consulting fees, and other rewards, when based upon merit, are all desirable. Too often, though, economic incentives are viewed with suspicion whenever public and private funding have common goals, as in defense or health. Market dynamics become essential to drive raw scientific advances toward economically meaningful

technological success. A glance at other countries around the world is sufficient to show how inefficiently R&D links with production unless economic incentives activate the linking process.

However, Federal support of R&D--i.e., public funding of early explorations, without a great range of economic incentives--also is essential in many (not all) fields and for many specific major projects. The reason, of course, is that there are also powerful economic disincentives to the private funding of high-risk, high-gain research. Frequently, an individual corporate investor would not gain enough in research to justify the risks. For example, few chemical and pharmaceutical companies invested in fundamental molecular biology during the 1960s; but NIH and NSF steadily built the base on which firms now safely stand.

Another classic case is the Federal funding of the fields leading to the remarkable increases in performance/price ratios for computers, based in part upon the Federal support of progress in electronic materials. The market soon assured sufficient incentives for sustained R&D. While Federal R&D funding continues to be needed in basic electronics, it might be less critical if international competition (mostly from countries with robust economic incentives for private firms) had not emerged so dramatically and did not involve such high levels of a combination of governmental and commercial investments.

A third elementary premise is that mutual interests build partnerships. Problems of collaboration among universities, industry, and government are not caused generally by a profound incompatibility (or an inherently adversarial relationship) between the R&D components of the sectors. If they were, laws and contractual negotiations--with due respect to Congress and counsel--could not solve them. Yes, there are

complex issues of patents and profits for industry and its partners. Yes, there are shifting social and scientific fashions for the patrons among the Federal mission-agencies. Such complex issues and Washington cross-currents do get contentious. But Washington cannot legislate greater creativity nor mandate specific coalitions for R&D. Laws and negotiations only smooth the way for what investigators and their institutions, in practice, judge to be healthy collaborations on a case-by-case basis.

This premise does not imply, Polyannaishly, that the various patrons and performers of R&D usually have identical goals, for that is not the case now and probably never will be. Yet there will be certain overlapping purposes and complementary motives. For example, universities may be prepared to wait a few weeks in publishing a paper emerging from corporate-sponsored research if the delay leads to a patent that may produce royalties; the underlying freedom to publish is not violated gravely by such a short delay.

There will also be divergent views and competing purposes. For instance, informed observers in Congress may differ on whether certain DoD-funded basic research, no matter how excellent, ever will yield utilitarian value for a soldier; but DoD scientists and university investigators may have mutual (and partly different) reasons for pursuing the effort. Each sector must be clear, of course, about its distinct principles and mission. Campuses must be open while corporations frequently are not. Federal agencies are accountable each year to Congress while universities see their research priorities in terms of decades. Federal agencies and universities also must have an informed sensitivity to commercial goals, accounting for the cost and risk of research in relation

to general business cycles. The test is whether, on balance, mutual interests spread broadly enough. If they do, then the parties adjust to each other's interests and unify their comparative advantages to achieve the goals in mission-oriented R&D.

A Federal agency has to decide, for example, what areas of basic research fit its long-range mission. Then the agency can invite a university investigator (or several) whose research aims match the agency's aims to form a liaison consistent with incentives that match the investigator's style and the investigator's institutional policies. The agency also must build adequate in-house scientific competence or it cannot chart its long-range aims with sufficient cogency to be confident about, much less manage, the mutual scientific interests to be served by the effort. The same pattern, of course, applies to corporations.

The Federal government has a unique responsibility to facilitate knowledge of R&D trends and promote communications at all levels in the private and public sectors. If this is done well, the three premises can be expressed in national efforts that succeed. What causes trouble are the revolutionary waves that often emerge either from R&D (e.g., VLSI or rDNA) or from the economic environment (e.g., the new trade problems internationally). These waves cause organizational strains that distract participants from proven practices. Just as in politics, where "a revolution is not a dinner party," organizing for technological change is rough.

Today, scientific and commercial competitions are tough, the social stakes high, and the Federal choices wrenching. Yet the three premises of our historical pluralism remain valid.

3.3 Historical Patterns: Dispersed Strengths

To understand the historical patterns, let us examine the dispersed strengths caused by the pluralism in mission-oriented research. One introductory point is that there is a history of the subject.(17) It encompasses the evolution of vaccines and lasers, of farm equipment and computing machines, of innovations along Route 128 and in Silicon Valley, and from before the 19th century through the entire 20th century. The historical strands involve individual scientists and theoretically inclined inventors interacting from and within the research community -- via diverse paths -- with engineers and the technological community associated in major markets. Many recent debates about governmental-corporate-academic links in R&D ignore the patterns and lessons of this history, probably at our peril.

From the late 1950s to the early 1970s, most academic investigators became complacent with growing Federal funding for basic research. For other reasons, the industrial R&D world also was content to let Uncle Sam fund most of the basic research. So university-industry links weakened. In parallel, during much of the past thirty years, no one paid consistent attention to the declining quality in scientific and mathematical education in elementary and secondary schools. Generally, then, despite a briefly energetic response to the shock of Sputnik, the country was coasting in its R&D, confident about what seemed unchallengable leadership in theory and practice, in intellectual vim and commercial vigor.

With overconfidence was bred a drift into seeing institutional stereotypes and tidy compartments of roles in R&D: research at universities

sponsored by Uncle Sam, development in industry, and a blithe faith in links being made whenever needed by a never-ending supply of well-trained personnel. This syndrome seems to have been particularly strong, although rarely expressed so crudely, among those benefiting most from the booming years of the mid-1960's. Now we are trying to work our way out of the limitations that these stereotypes imposed on the views of industry, government, and academe about each other.

Instead of these stereotypes of highly differentiated roles, what has been best in U.S. pluralism is the dispersal of strengths in R&D. This has enabled good linkages, high mobility of ideas and people, and flexibility in organizations responding to changing needs. Three propositions will sharpen this abstract theme. First, there is good science in industry and government. Second, there is a capability for effective invention at universities and in government. Third, there are many essential interactions between technology and science. Consider a few perspectives on these points.

To get at the issue of science in industry and government, we might check all Nobel Prizes to U.S. scientists (i.e., the sites of work, not citizenship) awarded in physics, chemistry, and medicine.(18)

Figure 1

U.S. Nobel Prize Winners in
Physics, Chemistry and Medicine
(1901-82)

University	Industry	Government	Other	Total
107 (85%)	9 (7%)	5 (4%)	5 (4%)	126

A total of 14 Nobel Prizes, or about 11%, went to industrial and governmental scientists. That is roughly proportional to the total funding, over this history, for basic research in those sectors. In other countries, scientific work is carried out more frequently in govenmental and "other" institutions.(19) These data cover only up to 1982; but the ONR scientists who shared the 1985 Nobel Prize in Chemistry confirm the trend.

This gross index suggests that where serious basic research persists over long periods in industrial and governmental units, it can produce world-class science of the quality that the Nobel Prizes are designed to recognize. Moreover, since selecting Nobel Prizes is a small lottery in some sense -- i.e., few, if any, mediocre scientists ever get one, but there are also many superb scientists who do not -- other individuals of Nobel Prize-caliber are working in governmental and industrial laboratories.

Another interesting index is our U.S. "elite" scientific group, the National Academy of Sciences. Here is a compilation of all members of the National Academy of Sciences, a total of about 1500, broken out by institutional sector.(20)

Figure 2

National Academy of Sciences

Institutional Affiliations (1985)

University	Industry	Government	Other
1170 (77%)	88 (6%)	88 (6%)	170 (11%)

Again, the total combined percentage from government and industry is about 12%, roughly proportional to the funds devoted to basic research inside the industrial and governmental agencies. Remember that since academics dominate the self-perpetuating election process in the NAS, the leading university scientists are voting for these fine investigators employed in industry and by government.

Lastly, consider data for the roughly 1200 members of the "elite" National Academy of Engineering.

Figure 3

National Academy of Engineering

Institutional Affiliations (1985)

University	Industry	Government	Other
461 (37%)	668 (55%)	59 (5%)	35 (3%)

For this group, the numbers naturally shift toward the largest fraction, 55%, coming from industry where most engineering and development goes on. The point here is that there is considerable high quality engineering at universities and governmental groups. Judged by peers in engineering, most of whom come from industry, almost half of the best engineers in the country are not employed by industry. This statistic suggests that campuses and governmental technical installations have good capabilities for distinguished engineering, which may be critical for significant invention, innovation, and the diffusion of "practical" ideas.

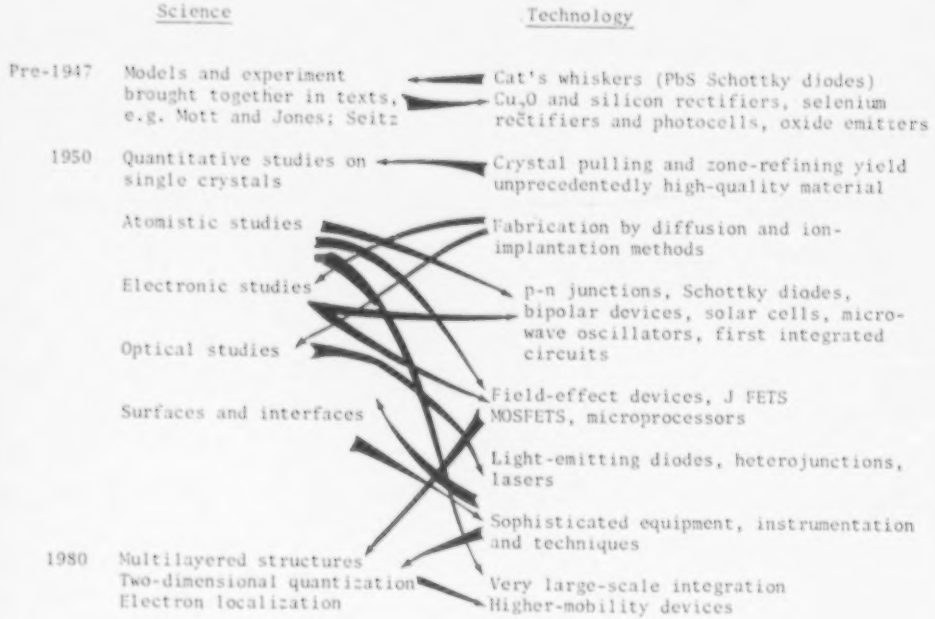
Another too-often-underrated proposition is the goal of fostering

creative feedbacks between science and technology. An excellent case is the history of solid-state physics.

From the late 1930s to 1980, viewed by a leading solid-state physicist who dissected the interactions between science and technology, this diagram of the 40-year period of astounding progress in semiconductors and related fields shows the power of interactions and dispersed strengths among the R&D institutions.(21) Often, we see, interactions do not follow the journalistically simplified linear model: basic research leading to new knowledge, then to an idea for practical applications, into detailed development, and finally to production and marketing. Instead, the arrows go in all directions. Some interactions happen rapidly, some take decades. In fact, roughly the same number of insights feed out of technology into science, as feed into technology from science. For example, the development of new ways to lay down molecular layers on crystals opened up new conceptual vistas; and theoretical insights led directly to the technological innovations embodied in scores of solid state devices.

As the diagram also shows, the modern story begins with two remarkable textbooks. They were seminal and had, in their way, great commercial importance as well as academic influence. One written by Frederick Seitz -- on solid state theory and experiment -- was the textbook that most professionals who work in the semiconductor industry and are, say, over the age of 40, used as their foundation when they were going to graduate school, often with governmental fellowships under the remarkable G.I. Bill. No surprise in that anecdote. It is just one more reminder of the importance of a powerful synthesis of fundamental ideas, particularly when the educational system is working and pluralism is fostered.

Synergism between physics and semiconductor technology


Science
Technology
Pre-1947
Models and experiment brought together in texts, e.g. Mott and Jones; Seitz
Cat's whiskers (PbS Schottky diodes)
Cu2O and silicon rectifiers, selenium rectifiers and photocells, oxide emitters
1950
Quantitative studies on single crystals
Crystal pulling and zone-refining yield unprecedentedly high-quality material
Atomistic studies
Electronic studies
Optical studies
Surfaces and interfaces
Fabrication by diffusion and ion-implantation methods
p-n junctions, Schottky diodes, bipolar devices, solar cells, microwave oscillators, first integrated circuits
Field-effect devices, J FETS MOSFETS, microprocessors
Light-emitting diodes, heterojunctions, lasers
Sophisticated equipment, instrumentation and techniques
1980
Multilayered structures
Two-dimensional quantization
Electron localization
Very large-scale integration
Higher-mobility devices

Adapted from
T. H. Geballe
Physics Today
November 1981

This pattern of interactions between science and technology is also seen in the biomedical sciences. It is hard to find, for example, even a remote laboratory today in molecular genetics without sensitive instruments for separating and purifying cellular constituents. These instruments have made it feasible to pose deep, researchable questions that were almost unimaginable a decade ago. Commercial products are being spawned directly on biological research frontiers that became reachable only with the aid of Federal support to establish the underpinning for these new technologies.

The underlying theme of these observations on dispersing our strengths among the R&D institutions and sectors is that an individual Federal agency can best orchestrate both short-range and long-range R&D efforts when it takes advantage of (rather than delimits) the diverse expertise distributed among all three sectors. Encouraging mobility and competition -- with some stable funding -- takes advantage of each sector's traditional strengths. Yet if a mega-agency attempted to do this simultaneously for all or most of the social goals served by science and technology -- from space to commercial standards -- there would be an inevitable tendency to classify, stereotype, and homogenize the roles of institutions.

3.4 Federal Patronage: Fashions and Complexity

With this complexity comes the untidy pluralism of Federal roles in managing R&D. It means multiple Federal R&D styles and occasionally even inconsistent programs. We have had, it must be conceded, some fragmented

policies over the past generation from that great patron of science, Uncle Sam.(22)

Overall, as we know, agencies across the government differ in their traditions and strategies for supporting research. On balance, that has been healthy, while we could afford it. The Department of Defense helped to "colonize" crucial modern fields such as geophysics, electronics, meteorology, and satellites; later, DoD changed its priorities for some of these areas. Recently, the DoD stepped up to help meet the nation's need for improved instrumentation in universities. NIH probably has the clearest tradition of sustained mission-oriented basic research. Yet the institutes are named for diseases. That is no accident, for the names reflect what is politically necessary and socially useful; while most of the research that NIH actually supports is relatively fundamental, a long way from the doctor's office. The National Science Foundation has certain major independent roles and it often has a "gap-filling role," i.e., helping those scientific fields in which, for whatever reasons, there are good scientists working while the fields temporarily are not either popular or mandatory for the mission-oriented agencies. Agriculture, Commerce, NASA, State, EPA -- each has had a unique history with gaps, successes, and failures in R&D. The fabric of desirable continuity has been frayed by changing fashions.

Lest this seem so far to be a convincing argument for centralization -- at least in science and education, if not in technology -- we should consider the complexity from the vantage point of the Federal purposes in R&D as a whole.

For one thing, it is usually the individual missions that provide the best case for why R&D is needed. As an example, in agriculture

today, the promise of plant molecular biology becomes the driving rationale for an increase in total agricultural R&D. This added funding for molecular biology is not being traded off against support for the health-related research in similar basic projects.

Take an even more specific case, the Mansfield Amendment to the Defense Department's funding in 1969.(23) Although it was an obscure provision that only applied for one year, it seems to have been subtly important in the subsequent evolution of national science policy. With the force of the then-Majority Leader of the Senate, the Amendment said, in effect, that DoD could not support research unless it related directly to its mission. That mandate said: do little, if any, "basic" research. Ever since, many agencies apparently have been affected informally by that now-dead law, symbolizing Congressional misgivings about "basic" research (read, "possibly irrelevant" research) in the large mission-oriented agencies. But this effect would have been much more severe if there had been a single Department of Science facing a generalized injunction questioning all support of basic research.

Another issue is that there are, in practice, many national economic and political decisions that create fissures in the pluralistic R&D approaches of the Federal mission-agencies. Any single agency responsible for "science" could never command the resources to meet all of these needs. For instance, a decade or more ago, when budgetary restraints and high inflation compelled most Federal agencies to ignore the capital needs of universities, no one sponsor conceivably could have come up with the funds that cumulatively have become a $5-20 billion shortfall in the facilities and instruments required for academic research and education.(24) Another example is the current turmoil about which Federal

agencies will participate, and in what ways, in fostering and regulating the sciences that feed the biotechnologies serving health and agriculture. Other fields also pose special issues, such as energy, in which since the early 1970's Federal agencies have presided over enormous fluctuations in R&D funding among industrial groups, the national laboratories, and universities. Such fluctuations and gaps have not been conducive to a healthy, competitive pluralism and, instead, have produced inappropriate signals for technical personnel in the labor market and even waste of scarce R&D talent.

Yet these problems did not arise silently, nor were they ignored by senior scientists and engineers. They arose, instead, from front-page controversies and White House decisions over which a hypothetical Department of Science and Technology probably would have had little influence.

3.5 International Trends: Stressing National Organizations and Budgets

At several points in this statement allusions have been made to the new international stresses on the Federal agencies supporting R&D.

Most important today is the comprehensive international competition in trade-spanning commodities, products, and services, all ranging from low-to high-technology. For this race, our national problem is neither technology *per se* (in which we often lead) nor the Federal funds for technological improvements (which has been comparatively generous). Instead, there are other factors: the technical literacy and social discipline of our work force; relative international rates of productivity increases; Federal deficits; interest rates; exchange value of the

dollar; savings rates and capital availability; tax incentives; and, above all, the increasing sophistication of our trading partners and competitors. These deep-running, almost intractable issues are beyond the scope of this paper. Yet they helped to produce justifications for the recent, authoritative recommendation to form a Federal Department of Science and Technology.(25) In effect, it was argued that "orchestrating national R&D" is an easier, and possibly politically more acceptable, path than any other when aiming toward improvement in our trading positions. Although those justifications evidently have not been convincing enough to change the pluralistic patterns reviewed earlier here, international trends are growing more important for the future.

Three other issues are closely linked with the R&D community, and these I highlight briefly because they show certain problems in pluralism.

One is research in the social sciences pertinent to foreign policy and particularly to national security and economic trends. Although I am neither an expert on the history of this subject, nor on the individual fields involved, it is too seldom discussed candidly in the frame of what Federal R&D "ought" to do.

The largely forgotten flap in the late 1960's about Project Camelot, a DoD-funded study of the sources of revolutionary movements, exemplified a terrible dilemma in Federal sponsorship of internationally relevant social research.(26) Most agencies with a need for such knowledge do not have the resources to carry out the work; while DoD, with both the need and the resources, constantly bumps into understandable public and Congressional sensitivities about "militarizing" scholarship and the policies flowing from it. The corrosive domestic debates about how and why

we got into Vietnam worsened this dilemma. But the issue was there for many years before Vietnam. It remains as a peculiarly crippling example of the general tensions when power and knowledge converge.

Because the social sciences usually elicit greater Congressional attention than the physical sciences -- certainly on a per dollar basis -- whenever an agency gets into social research, it can expect debate. The consequence is that the Federal government's support of research is meager in those social sciences relevant to the always debatable choices in foreign policy, national security, and global socioeconomic trends such as terrorism.(27)

After a comparative boom in the late 1950's through the mid-1960's, academic centers of social science were virtually starved out of existence for most of the 1970's and into the early 1980's. Sensitive studies of the Soviet Union, China, Middle East, Latin America, Asia, Africa — of almost any foreign area, related to cross-cutting international problems -- were forced to go for support almost entirely to private groups. Recently, both Federal and private support have increased slightly. But these new streams of funding are fragile.

To repeat, we know we need more than a small band of specialists on Japan, on the Soviet Politburo, on tribal loyalties in Africa, or regional military forces in China. Yet we do not have a robust Federal research effort. No agency wants to take the lead. The 1985 controversies about an openly disclosed CIA grant to a professor organizing a conference on Islamic Fundamentalism -- and about DoD inviting applications for support of regional studies -- remind us that it is still very difficult to start, much less maintain, such Federal programs.(28)

An international issue of a different kind is the R&D relevant to

developing countries. This is, in part, a subset of the problem just mentioned regarding sensitive social research; but it also extends to the comparatively less controversial task of analyzing economic data on the performance of individual countries in terms of development theories, social organization, and financial flows of aid, credit, and investment.

Even worse, there is the additional gap of effort on an enormous range of goals in the "hard" sciences and engineering: low-cost housing materials; urban water and transportation systems; malaria and schistosomiasis; the genetics of major food crops; population planning techniques -- the diverse issues that boil over in the so-called "third world" and that may be ameliorated, in part, by technologies developed and introduced humanely with the aid of the developed countries. This is such an extraordinary subject that I cannot do justice to any of its details here. Many specialized technical reviews are available and, over the past 25 years, many U.S. and international conferences have been held on both the scientific opportunities and the modes of global collaboration.(29)

The bureaucratic perspective of interest in this testimony is that these subjects always "fall through the cracks" in the Federal mission-agencies' approach to their R&D. The reason is simply put: Congressional sentiment, reflecting the public's attitude, strongly emphasizes domestic needs for science and technology. International problems that do not touch many of our citizens directly just do not command resources. Nonetheless, AID and the State Department bravely attempt to work on many of these matters. But they are second-guessed by critics and shackled by constraints from every quarter at all times. Whenever a regular mission-agency such as NIH or NBS or NSF starts a new program aimed at such an

international (i.e., mainly non-U.S.) problem, the budget is always in jeopardy. The international agencies such as UNESCO or FAO often are either politicized or inefficient, or both; and U.S. contributions to these agencies are thus also always in jeopardy. When R&D budgets are tight, even outstanding U.S. scientific programs pursued in an international context -- such as in geophysics or climatology -- may be overwhelmed by the domestic political impulses to avoid international investments with their administrative complications. The cumulative result of all this is a far less than optimal level of U.S. R&D in the international contexts for which the U.S. has both a moral responsibility and a large economic stake.

Turning to the fourth of these international themes, the DoD's 6.1 and 6.2 programs might be regarded in part as "leading indicators" of arms control issues that could emerge in the future. Even a casual reading of unclassified "arms control impact statements" reveals the tradeoffs among, restraints on, and lively pace of newer technologies interacting with decisions on national security/arms control policies.(30) The more policy-oriented assessments of the same issues -- such as the Defense RDT&E (and acquisition) program -- refer repeatedly to the impacts of research on choices for deployment and for negotiation (and vice versa).(31) Verification of urgently desired nuclear arms reductions, to cite the most obvious example, depends heavily upon advanced technical means (developed largely at universities and in industry) and upon the interpretations of highly trained analysts (most of whom are career employees of the in-house laboratories and FCRC's).(32)

Although it is not possible here to treat this subject fully I emphasize it because it is a clear example of the "internationalization"

of policy-making about the national R&D effort. Whether the arms control issue is non-proliferation of nuclear weapons to the third world or super-power talks on offensive missiles, the research community is involved. Whether the goal is avoiding technological surprise that could be destabilizing strategically, or pressing for NATO sharing in the procurement of more compatible systems that would strengthen the European deterrent, the programs and staff in basic and applied research play a role, sometimes minor and occasionally central.

Would a single Federal Department for Science and Technology likely deal effectively with these four matters? I doubt it. Comparative advantages in trade go well beyond the likely portfolio of the head of such a department. The social sciences have been vulnerable to disputes and budgetary slashes even where they seemed to fit easily, such as at the NIE and in the OEO. International R&D programs will not compete well against domestic R&D when so many U.S. scientists and engineers have so many projects and mouths to feed at home; and a new national agency would not assign its highest priority to such global tasks in any case. Arms control, and defense R&D, surely would not be the main concern of the hypothetical, more unified Federal science agency. Nonetheless, the hypothesis about a new department underscores at least these four striking issues in our pluralism organized around domestic missions -- and it becomes, therefore, a useful prod for thinking about how to improve our present system.

3.6 Final Note

The pluralistic model is consistent with Pasteur's aphorism: "There is only one science and the application of science, and these two activities are linked as the fruit is to the tree." Each tree needs independent nurturing, and each mission needs research.

4. Brief Responses on Five Areas in Statement of Purpose for SPTF Hearings on Science in the Mission Agencies and Federal Laboratories

In this section I offer selected responses with respect to the five broad areas identified as the focus for the October 1985 hearings.

Coordination and Management. The influence of external advisory groups to each agency -- and of the Federal Council in inter-agency efforts -- shows signs of being weaker than it should be for pluralism to work at its best. As outlined earlier, when an agency's basic research component is weak, ties to the independent technical community are attenuated. Furthermore, when all Federal R&D budgets are tight (as we know they were for most of the 1970's) and when new technical issues cut across traditional agency lines (as in uses of space), inter-agency cooperation is both more desirable and more difficult. Rarely, however, is "wasteful duplication" the issue; competition tends to reduce that to almost negligible proportions. Instead, the chronic issues are: Which good ideas should be supported? Which cogent advisor's recommendations make the most sense? Which agency should take the lead? OSTP and OMB possess the clout to bring clear concepts and decisive proposals into these matters, and they often have done so through new priorities.(33)

Extramural Relationships and Infrastructure. The classical consid-

erations in Federal R&D management -- orchestrating people, facilities, communications, cooperation, and stable funding while taking account of all performers -- have not always been expressed fully over the past 15 years. This occurred largely because the earlier era of rapidly rising budgets made it too easy to trim and trim during the more recent year-to-year squeezes. We paid too little attention to the accumulating deficits in the infrastructure. The mission-agencies often publicized the implications of the trends; but resources were thin, and decisions often were expedients. A national experiment with abolishing the White House science office didn't help matters. The inexorably rising costs of instrumentation needed for each investigator made matters worse. Now, finally, widespread political attention focuses on the problems as a whole. Solutions will evolve slowly in terms of overall budgetary limits; and 5-10 years probably will be needed under plausible budgetary scenarios.

Regulation-Driven Research. Many observers have noted the absence of a steady priority on R&D among the agencies for which this question is critical. The FDA poses different issues than the NIH's RAC for the appropriateness and scale of in-house laboratories and significant extramural research. In the DoD, the test-and-evaluation functions have often drawn upon in-house talent in ways that might be viewed as the functional equivalent of meeting "regulatory standards." Although I have never been immersed in this area, anecdotal evidence and intuition lead me to believe that a key issue is the long-running lack of funds and "high science" in many of the relevant fields (such as toxicology). This is amplified by the frequent clash of economic and ideological interests about the usually shaky foundations of any regulation's interpretation.

Federal Laboratories. The Packard Panel's penetrating observations and recommendations have been followed up through the agencies.(34) But "reform" is obviously not an easy task, as previous Administrations have seen. My limited experience in this area leads me to emphasize two fundamental points. First, R&D chiefs need clear purposes, within a budgetary limit, and then delegated authority on how best to assemble their resources to achieve these purposes. Too often, there are detailed controls on everything -- personnel, budgets, contracts, reports, and other variables -- all within rapidly shifting, or fuzzy, missions. Second, agency heads should employ more independent, "peer review" procedures for major promotions and other rewards to the R&D staffs. Quality and productivity in the better Federal laboratories tend to prove these elementary notions.

5. Concluding Remark

This Committee all too frequently hears the commonplace assertion that science and technology move quickly these days, so quickly that our institutions cannot cope with the pace. The assertion is common because it is true. But it also is misleading in some ways.

The origins of the spectacular principles and tricks of genetic engineering go back several decades; yet the markets for genetically engineered products remain very small, although the potential is great. The first operating masers, the precursor for lasers, were built 30 years ago; yet the related technologies are still correctly portrayed as "new" (even revolutionary) in many applications.

Similarly, it is not at all clear that our old institutions -- even in the admitted absence of a grand plan -- have been incapable of handling the pace of contemporary technical change. DARPA, for example, was created within DoD in 1958 and has enhanced the flexibility for mission-oriented defense R&D. The NIH, a "science-agency" in the minds of many, has invented useful quasi-regulatory roles that work well in guiding its interfaces with potentially risky laboratory work and with the ethics of clinical research.(35)

In short, the modern technical pace is too easily overstated, and the faster pace is no cause for institutional panic. Stability in international security probably continues to rest upon steadiness, including a vigorous R&D program designed to avoid surprises strategically and open up options for cost-effective modernization.(36)

In the preface to a 1959 monograph about electronic devices, there is the following quotation:

> "The earth is degenerating these days. Bribery and corruption abound. Children no longer mind parents. Every man wants to write a book, and it is evident that the end of the world is approaching fast."

An earlier appearance of this quotation was on an Assyrian tablet in 2800 B.C.

6. References and Notes

1. See, for example, historical account in Science at the Bicentennial, National Science Board, 1976, US GPO, pp. 14-15; and more recent series from OMB and NSF such as NSF 84-82 and NSF 84-311.

2. The Economics of Defense Spending: A Look at the Realities, July 1972, Comptroller, Dept. of Defense, Washington.

3. See, for example, Labor Market Analysis of Engineers and Technical Workers, G. Cain, et.al., Johns Hopkins Press, 1973; and "The Job Market for Engineers, Recent Conditions and Future Prospects," D. Braddock, Occupational Outlook Quarterly, Summer 1983.

4. Projected Response of the Science, Engineering, and Technical Labor Market to Defense and Nondefense Needs: 1982-7, NSF-84-304.

5. Manpower Comments, June 1985, pp. 1-3.

6. See, for example, R&D, Patents and Productivity, Z. Griliches, ed., Chicago, 1984; and Technology Transfer, Productivity and Economic Policy, E. Mansfield, et.al., eds., Norton, 1982.

7. See, for example, The Economics of Peacetime Defense, M. Weidenbaum, Praeger, 1974.

8. Statistical Abstracts of the United States, 1985

9. For 1985, the Defense Science Board's 30 members include 23 from industry (and related consulting or predominantly DoD-funded non-profit centers) with 7 from universities. Several retired military officers and 2 Nobel Prize winners are members.

10. See, for example, the series of articles and related surveys of literature in International Security, including the Fall 1985 issue, Center for Science and International Affairs, Harvard, and MIT Press, Cambridge, Mass.

11. For sophisticated examples of analysis of the roles of technology in defense, see Thinking About National Security, Harold Brown, Westview, 1983; and Coalition Defense and C3I, Mitre Corporation, Bedford Mass., 1983.

12. Scientific Communication and National Security, National Academy Press, 1982, p.47.

13. See, for example, U.S. Military R&D Management, Center for Strategic and International Studies, Georgetown Univ., Wash. D.C., Spec. Rept, #14, 1973.

14. See, for example, DSB Task Force on Technology Base Strategy (October 1976) and DSB Summer Study Group on Fundamental Research in Universities (Oct. 1976), ODDR&E, Pentagon, Wash. D.C.

15. See, for example, the superb essay by Harvey Brooks, in Current Science and Technology Policy Issues: Two Perspectives, George Washington University, February 1985. For a critical attack on the post-WW II patterns, see Lost At the Frontier: U.S. Science and Technology Policy Adrift, D. Shapley and R. Roy, ISI Press, Philadelphia, 1985. For an analysis of the intellectual forces underlying the historically chronic tensions in science policy, see America's Unwritten Constitution: Science, Religion, and Political Responsibility, Don K. Price, Louisiana State Univ. Press, 1983.

16. Vannevar Bush's 1945 report entitled Science - The Endless Frontier, reprinted May 1980 by the NSF, contains an even more balanced view of mixed institutional arrangements and national goals than its image of emphasis on research usually conveys.

17. For succinct, wise accounts of the trends affecting universities in the post-WW II era, see Academic Science, Higher Education, and the Federal Government, 1950-1983, J.T. Wilson, Chicago, 1983; and The Home of Science, D. Wolfle, McGraw Hill and Carnegie, 1972.

18. I am indebted to Harriet Zuckerman, Columbia, for authoritative records and analyses of Nobel Prizes.

19. See, for instance, an excellent NSF-STIA report by L.L. Lederman, entitled "Recent Changes in Science and Technology Policy, Priorities, Practicss, and Programs in France, FRG, Netherlands, Sweden, and UK," December 1984.

20. I am indebted to Don Philips and Ken Fulton, National Academy of Sciences, for authoritative data on NAS/NAE membership.

21. Physics Today, T.H. Geballe, November 1981.

22. Basic Research in the Mission Agencies, National Science Board, 1978, NSF and US GPO.

23. "Mission-Oriented R&D," R.W. Nichols, Science, 2 April 1971, pp. 29-37.

24. See, for example, Academic Research Equipment in Selected Science/Engineering Fields, 1982-83, NSF, August 1985; and Academic Research Equipment and Equipment Needs in the Biological and Medical Sciences, NIH, April 1985.

25. Global Competition: The New Reality, Report of The President's Commission on Industrial Competitiveness, chaired by John Young (Hewlett-Packard), January 1985, U.S. Gov. Printing Office.

26. The Best-Laid Schemes: A Tale of Social Research and Bureaucracy, S.J. Deitchman, 1976, MIT Press.

27. See, for example, Carnegie Corporation of New York, Annual Report for 1984, and David Hamburg's report on "Prejudice, Ethnocentrism, and Violence in an Age of High Technology."

28. New York Times, Oct. 12, 1985, p.13, regarding Professor Nadav Safran at Harvard's Middle Eastern Research Center.

29. See, for example, extensive State Department and NAS/NAE/NRC papers related to the U.S. preparations for the UN Conference on Science and Technology for Development, held in Vienna, 1979.

30. See, for example, Fiscal Year 1986 Arms Control Impact Statements, April 1985, Joint Committee Print, 99th Congress, 1st Session, U.S. GPO.

31. See, for example, The FY1986 DoD Program for Research, Development and Acquisition, Statement by Under Secretary of Defense, Research and Engineering, March 7, 1985, Pentagon, Wash. D.C.

32. See, for example, The Verification Challenge, R. Scribner, T. Ralston, and W. Metz, under auspices of AAAS, Birkhauser Boston, 1985.

33. See, for example, "Four Years of Reagan Science Policy: Notable Shifts in Priorities," G. A. Keyworth, II, Science, 6 April 1984.

34. Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel, Vols. I and II, July 1984, OSTP, Exec. Off. of President, Wash. D.C.

35. For a splendidly cogent and broad review of professional and institutional approaches to ethical decisions, see Modern Science and Human Values, W. W. Lowrance, Oxford, 1985.

36. Research and Development and the Prospects for International Security, F. Seitz and R. W. Nichols, Crane Russak, New York, 1973.

Mr. FUQUA. Thank you very much, Mr. Nichols.

Norm, on the question that you raised and certainly a very important question is about research conducted in colleges and universities. Where would basic research be conducted if it were not conducted—if we have a tilt too far to research in colleges and universities?

Let me paraphrase that a little bit by saying that one of the witnesses that I recall testified came from industry, Roland Schmidt, and is now Chairman of the National Science Board, testified that in colleges and universities—and particularly I am speaking of the graduate programs—is where we really train the scientists that you use in industry and the Government uses in the national labs and so forth. The way that we can stimulate that interest in conducting research and becoming involved in it is in the years that they are in college and doing graduate work.

If we didn't have that, where would it be conducted and would we train the scientists that we need for industry and the Government and so forth?

Mr. AUGUSTINE. I believe that universities are probably one of the most promising places to perform research as part of the training process.

Mr. FUQUA. I am speaking of basic and fundamental research, not necessarily applied.

Mr. AUGUSTINE. The point I guess I would like to leave with the committee is for what the DOD would call 6.1 and 6.2 research or applied research, the universities are an ideal place to perform that as long as it is not done at the expense of quality education. That was really the point I was trying to make.

Mr. FUQUA. That is a very important point.

Mr. AUGUSTINE. I do think that there are also the relationships with universities that can be set up where fine research can be done on a continuing and larger scale basis than perhaps the universities themselves can take on. That might be through research institutions that are somehow associated with universities, the word loosely as used in the agenda that your committee prepared. There are examples of such institutes that draw upon the faculty, that draw upon the graduate students, and they have full-time professional staffs.

I think some of those relationships with universities to complement the smaller programs the university itself can afford to embody, I think that is very promising.

In fairness, I should say I think it is possible to do good research in the industry. As I said, there are a few examples of it. The problem is not the quality of the people in industry. The problem is the lack of funds from the corporate sources itself that you dare to place in research and still be competitive.

That is a long answer to your question, but I think we have to count on the universities and institutions related to the universities to be the doers of research in this country, by and large.

Mr. FUQUA. How about some of the big science programs—let me address this to both of you—like high energy physics and nuclear physics such as what is conducted, say, at the Fermilab, discussion

of the Superconducting Super Collider, or atmospheric work that is being conducted at NCAR in Colorado, and a lot of these in the national energy labs or even in NASA, for that matter, where they are doing fundamental research in aeronautics or propulsion systems that probably extend beyond what industry could or could afford to do or even attempt to do, say, wind tunnels that are large, expensive, and every company doesn't feel like they can afford facilities of that type and is an appropriate role for the Government to be involved in some of those.

Mr. AUGUSTINE. I think those are good examples of where it is appropriate for the Government to be involved; namely, projects that require large teams of people and very costly facilities that nationally you just couldn't replicate over and over. I do believe, though, that as has been the model with NASA wind tunnels and the national labs, they make those available to industry and researchers from universities.

So, I don't believe there is any reason that use of those facilities has to be solely by people on the Government payroll. They can be people from industry or academia that come in and share those facilities and work together much along the model that we have seen in Japan. I think that would be a very constructive thing to do.

Mr. NICHOLS. I agree with you, Mr. Chairman, if what I think you are getting at is sort of hybrid institutions that bridge these stereotypic boundaries. There are examples in biology. The place where I work was started as the Rockefeller Institute for Medical Research. It granted no degrees and did quite nicely for 50 or 60 years doing basic research without being a university, without being industry.

There are a number of such examples. The most recent one that received a lot of publicity is called the Whitehead Institute which has a sort of an uneasy relationship with MIT in Cambridge and is led by David Baltimore, a distinguished molecular biologist. It is, in effect, a freestanding basic research institute and does not grant degrees.

I suspect that those innovations will be needed. If that is what you are getting at, I agree.

Mr. FUQUA. How do you think the Department of Defense can determine what basic research is relevant to its mission? I would ask that of both of you.

Mr. NICHOLS. I think my answer would be a little different than from what Yonas or Cooper said to you earlier. My hunch is that the best point of decision for that is at the level of the chief scientists, typically career chief scientists, in the three service research agencies and the people who are just below the Director of DARPA and frankly don't spend as much time on administrative matters and are closer to the technology.

The decisions about what is relevant inevitably involve debate because we have to go out 10 to 20 years, and there will certainly be no certain calculus about that.

Mr. AUGUSTINE. There is, as the committee well knows, a never-ending debate about whether there should be a requirement—pull for new technology based on what the operators need or should there be a technology—push based on what becomes available. There are two camps. I happen to believe that both are important.

I think the way the DOD can best approach the matter of prioritizing its research needs is to look at both those perspectives. First, what are the operational needs that we don't have? That then suggests technological capabilities one would like to have and suggests areas of research where you might explore.

On the other hand, I cited in my testimony any number of very important research breakthroughs that have occurred by people not looking for those particular breakthroughs but just because they were performing fine research in significant areas. So, I think one also has to have a parallel program where you work in areas of some promise but basically just go and do basic science, and you explore and you see what comes out of them. Sometimes, nothing comes out; sometimes, something very major comes out.

I think we have to allow our scientists a fair amount of latitude in what they do in the area of basic research, whether we are dealing with the Department of Defense or elsewhere.

Administratively, how you do that, I guess I would say, you do it with as little bureaucracy and guidance as required and make the decisions in the laboratories, not in the Pentagon.

Mr. FUQUA. Mr. Brown?

Mr. BROWN. Mr. Chairman, let me pass for the time being and go to Mr. Volkmer and Mr. Lewis.

Mr. FUQUA. Mr. Lewis?

Mr. LEWIS. No, thank you, Mr. Chairman.

Mr. FUQUA. Mr. Volkmer?

Mr. VOLKMER. I have no questions, Mr. Chairman.

Mr. BROWN. Mr. Augustine, you had a couple of statements in your prepared text that intrigued me a little bit. On page 6, you say very strongly that the DOD research—I am sure we are talking basic research—should be performed for the one and only purpose that it contributes to providing for the Nation's military security and should be supported to the degree commensurate with the risk one wishes to accept in the area of national security, which is a rather provocative statement because the degree of risk is a highly immeasurable kind of thing. Yet, you are dedicated in your allegiance to the need for healthy funding for basic research.

We have gone through this debate many times. It was a debate with regard to the relevance of basic research to DOD missions that led to the Mansfield amendment, as I am sure you recall. It is in the nature of basic research that it is pretty hard to determine whether or not it is going to have a direct contribution to a defense system.

How do we resolve that problem other than, of course, following the good judgment of the proper people which I am sure both of you would agree is important? Is there any way that we can do a better job of quantifying or setting boundaries on this question of support for basic research and how we can relate it to precise or even imprecise DOD needs?

Mr. AUGUSTINE. It is a very profound question. I have often heard in my career, particularly when I was with the Defense Department, arguments that we should spend more on defense this year because it will help stimulate the economy or because it will produce social benefits of some type.

Mr. BROWN. And you want to get away from that, obviously.

Mr. AUGUSTINE. I really do. I think that if you want to, you should perform in the DOD just that part of research and just those things that help with national defense. If the goal is to stimulate the economy or to perform in research in general, let me say, go do it somewhere else. Let the Defense Department concentrate on defense.

It produces a very tough judgmental question for the management, and that is how much should you spend on defense, particularly in the area of research. As you point out, you often don't know when you are doing the research whether it is for defense or whether it is for something else, and there are a lot of good examples, computer industry, communications satellites, and so on.

It gets to be an issue of how much risk you want to take, and we do take risks every day. Certainly, there would be less risk from the defense standpoint if the Congress were to increase the defense budget further. There is also a price to the Nation of doing that, and I am afraid I have nothing better to offer than that it is a judgment of qualified people as to how much risk you take as you increase or you reduce the defense budget, whether it be for research or otherwise.

I would say that within the defense R&D program, I believe and always have believed that the research budget should get first priority. It is No. 1. The reason for that is fairly straightforward. If you change the procurement budget by 10 percent, you probably change the operating capability of the forces by 10 percent. If you cut the research budget to the point you miss the Stealth airplane or the nuclear weapon or the longbow or the stirrup or whatever through history, you may change the capability of the forces by an order or magnitude.

I guess there is a Laffer curve in here that says if you put all your money into research, you have nothing to fight with and that is not the answer either. That is what makes it so tough to manage.

Mr. BROWN [acting chairman]. It becomes essentially a political judgment. Of course, you have mentioned some examples of where defense supported research made substantial nondefense contributions, computers, communications satellites, lasers, many others. But it is sometimes easier to get funding for research in the Defense Department than it is for research which is assumed to have a civilian application which, particularly today, we tend to say should be done by the private industry that would benefit from it.

That is the part that bothers me. We have some projects right now, for example, to take a recent one, the proposed research program on a hypervelocity spacecraft. There is undoubted military benefits from having that. Yet, there are tremendous civilian commercial applications from that.

It becomes a political judgment as to what you should do, first, the basic research—and there are some areas still requiring basic research—and then the applied research and exploratory development aspects of it. We are looking for guidance as to how we can better resolve that, but it is very difficult to perceive.

Mr. NICHOLS. I think you are certainly right that it becomes essentially a political or social judgment at the margin, but there are

quantitative indicators. We are not completely at sea, as you well know, Congressman Brown.

To perceive the defense mission as a high-technology mission loosely analogous to a high-technology industry and the high-technology firms, it wouldn't be amazing to have 10 percent of total sales spent on R&D. That is about where we are in the defense budget. Since you might expect that the Defense Department, since there is no other customer for its R&D, would have to fund more of the R part of R&D for the national mission, you might expect on that grounds alone just looking at indicators that the R part would be more R intensive in this monopoly, DOD, that is a high technology mission.

We are not a factor of 10 away from what that loose analogy would indicate.

Mr. BROWN. Gentlemen, I personally find your contributions to be extremely helpful and I am going to have to digest them for a period of time. I may have material for a number of speeches just out of your testimony.

We do have a rollcall on, and rather than hold you here, I think it would be best if we excused you and adjourned the task force. Thank you very much.

[Whereupon, at 12:15 p.m., the task force recessed, to reconvene on Thursday, October 24, 1985, at 9:30 a.m.]

57-279 O - 87 - 22

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

THURSDAY, OCTOBER 24, 1985

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SCIENCE POLICY TASK FORCE,
Washington, DC.

The task force met, pursuant to notice, at 9:36 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Present: Representatives Fuqua, Walgren, Lundine, Lujan, Packard, and Fawell.

Mr. WALGREN [acting chairman]. The task force will be in order.

Today's hearing is the last of six hearings that the task force has held on science in the mission agencies and the Federal laboratories. Today, we are going to try to focus on science policy in the Federal laboratories and also be exploring the issue of regulation-driven research.

The first witness, Dr. Lew Allen, is well known to the committee. As many of you also know, Dr. Allen is director of the Jet Propulsion Laboratory and a vice president of the California Institute of Technology. Prior to his appointment as director of the Jet Propulsion Laboratory in 1982, Dr. Allen held the rank of general in the U.S. Air Force and served as the Air Force Chief of Staff.

We are very pleased you could come, Dr. Allen, and join in this discussion with us. We appreciate your being a resource to this process and are glad you are here.

Let me ask if any of the other members would like to make any opening comments at the outset.

Mr. FUQUA. I would just like to welcome Dr. Allen and say that we are very pleased to have you and the other witnesses here today. As I mentioned to you, I apologize that I have to be in another place shortly, but I do thank you for your contribution on behalf of the task force. When we have your testimony, we will study it further.

Mr. WALGREN. With that, let me just invite you to proceed in whatever way you feel would underscore the points you would like to make. We appreciate having you and will make your written statement a part of the record and any written submission you would like to make will also be so. We invite you to discuss this subject with us.

[A biographical sketch of Dr. Allen follows:]

DR. LEW ALLEN, JR.

Dr. Lew Allen, Jr. is a vice president of the California Institute of Technology and the director of Jet Propulsion Laboratory. He assumed his duties Oct. 1, 1982.

Dr. Allen retired June 30, 1982, as Air Force Chief of Staff and a member of the Joint Chiefs of Staff. In the Air Force he held the rank of general.

He was born Sept. 30, 1925, raised in Gainsville, TX and graduated from the U.S. Military Academy at West Point in 1946 with a bachelor of science degree and a commission as a second lieutenant. He served as a pilot in the Strategic Air Command until 1950 when he entered the University of Illinois. There he received a master of science degree in 1952 and a doctorate in physics in 1954. Dr. Allen was then assigned to the Atomic Energy Commission's Los Alamos Scientific Laboratory as a physicist.

From 1957 to 1961 he was assigned science adviser to the Physics Division of the Air Force Special Weapons Center. And in 1961 he was assigned to the Office of the Secretary of Defense, Space Technology Office, in the Directorate of Research and Engineering, Washington, D.C.

From June 1965 to February 1973, he was assigned to the Office of the Secretary of the Air Force where he served in both Los Angeles and Washington in duties relating to military space systems, and in June 1969 became director. In April 1971 he became director of special projects, with additional duty as deputy commander for satellite programs, Space and Missile Systems Organization.

After serving briefly in the Air Force Systems Command at Andrews Air Force Base, Md., he was appointed in March 1973 as deputy to the Director of Central Intelligence for the Intelligence Community in Washington, D.C. In August 1977 he was named commander of Air Force Systems Command.

General Allen served as the vice chief of staff, U.S. Air Force, from April 1978 until he assumed his duties as Air Force Chief of Staff in July 1978.

STATEMENT OF DR. LEW ALLEN, JR., DIRECTOR, JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CA

Dr. ALLEN. Mr. Chairman, I am pleased to be here.

I realize that your inquiries relate to the broad science policies of the country, but I think that my contribution may be best to describe a particular mode in which the Government does research, and that is the one with which I am the most familiar, and that is how research is done by NASA using JPL. That will lead to some observations that I hope will be of some more general interest to you.

JPL is a NASA center. It is one of the nine NASA centers. It is the only one that is not a civil service center. We are a part of Caltech. All of the work that is done is performed under a single contract between NASA and Caltech. It is performed in Government-owned facilities. Therefore, JPL is what is technically known as a "Federally Funded Research and Development Center" where NASA is the sponsoring institution.

The contract is the document which specifies our mission and the conditions under which we may do work for other Government agencies. NASA assures the accountability of the appropriated funds that are provided and conducts, among many other reviews, an annual detailed performance evaluation.

This arrangement, I believe, has yielded excellent results over the years.

Our primary mission is the conduct of missions to explore the planets of our solar system. We also conduct other missions for NASA as they are assigned, and about 25 percent of our effort is for other Government agencies as approved by NASA. That is mostly Department of Defense these days.

The planetary missions are for science. The science objectives and strategies are formulated by the National Academy of Sciences. NASA uses boards and committees of external scientists to formulate plans to accomplish these objectives within budgetary guidance provided by NASA.

The scientific investigators for the missions are primarily university scientists, and that is by policy. JPL has internally a competent group of scientists who provide a minimum and necessary capability for the performance of our missions, but they must receive their support from NASA as a result of the peer review of proposals that they make.

JPL has no capital account and no pool of sustaining funds such as the RPM funds of the other centers. Our employees have no tenure, and if their work is not supported, they are discharged. This system, in practice, works well. It certainly deters complacency, and it motivates excellence.

Although our mission is space science, we are primarily an engineering lab with a characteristic of a full range of space system capabilities in-house, a doing laboratory. In general, over the years, we have had one major project that is the full range of the spacecraft system that is performed in-house, and then all others are contracted to industry. That is in order to ensure that we remain smart buyers and do not become too divorced from all of the skills that are required to execute space missions. In that sense, we are different from the other centers in that our ratio of in-house work and the extent of the in-house work is substantially greater.

NASA is a mission agency, but our mission is science. I think that planetary exploration has been a sound national investment, but that is not a U.S. judgment alone. The Soviets launch about twice as many spacecraft to the planets as do we. ESA, the European organization, and Japan are making major contributions and growing these days.

This particular arrangement has been good for Caltech. It has complemented the very basic research emphasis on the campus with a practical engineering emphasis at JPL. Students are attracted to Caltech by the proximity and relationship with JPL that ensures, to some degree, against Caltech acquiring an ivory tower attitude among its faculty as they pursue the fairly esoteric and basic research capabilities which are characteristic of the campus.

The close ties to the campus have provided benefits to JPL. They have provided a quality control for JPL. The ties to the campus have appeal to our employees. There is an intimacy of the relationship between JPL and the campus that is substantially greater than that that exists, for example, at Los Alamos and Livermore with respect to the University of California.

There are several faculty committees that review our work, and there is a committee of the board of trustees that pays particular attention to the activities at JPL.

The Packard report which has been discussed with your task force emphasizes a number of matters with which I agree. Some of these have been formalized in the OPM document dealing with FFRDC's and we are in compliance with those both in letter and in spirit.

One thing his report emphasized was that the laboratories need adequate flexibility in order to pursue rapidly innovative ideas. NASA provides JPL about 0.5 percent of the budget in terms of discretionary funds, that is, monies which can be used during the year to pursue particular items of research without the bureaucratic processes being required. That is up substantially from what it has been previously, and for that, I am pleased. But that is still small by comparison with other laboratories and what I think is sound judgment. There is a very considerable lack of flexibility that is inhibiting and does delay innovative research. There are many opportunities to pursue items which take too long.

We have taken increased work for Defense in the last few years. That work is constrained to about 20 percent of the total of our effort. Ten years ago, about 20 percent of our effort was for the Department of Energy and alternative energy sources, but that has shifted to Defense.

I think this work is appropriate. We can make a useful contribution, and much of the technology which DOD supports at JPL is very advanced and will later benefit NASA missions.

We do some classified work. Caltech allows none on the campus, and we must keep JPL generally open by the policies of Caltech. But the classified work that we do segregated at the laboratory is not a problem as far as I am concerned.

However, I am quite concerned about the present tendencies to control unclassified publications. The President's order recently has eased some of those concerns, but there remains considerable apprehension over what I believe are most dangerous trends in the country.

Our space missions are taking on more and more an international character, and I think that is highly desirable and will increase, and JPL is deeply involved in international missions of a number of different varieties.

We have very good people at JPL. We pay competitive salaries. I would like to note particularly to you that the average salary for scientists and engineers is almost exactly the same at JPL as it is at the civil service centers. Therefore, it is the flexibility which differs and gives us the opportunity to get, I believe, a substantially higher grade of employee. Our employees don't have any assured employment, as I said before. Yet, we are a very attractive place to work.

Other speakers have told you about difficulties with the civil service system and with contracting procedures for research. I believe that our experience shows that there can be a very cost effective, responsive, and fully accountable research operation without those inhibitions.

Mr. Chairman, with those brief remarks, I would be pleased to answer whatever questions you might have.

[The prepared statement of Dr. Allen follows:]

STATEMENT OF

DR. LEW ALLEN

DIRECTOR

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

before the

UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

SCIENCE POLICY TASK FORCE

October 24, 1985

Mr. Chairman and Distinguished Members of the Committee:

Thank you for the opportunity to give testimony to your Committee's Science Policy Task Force panel on "Science in the Mission Agencies and Federal Laboratories". I will discuss scientific activities and related policies at the Jet Propulsion Laboratory (JPL). Since some of you may be unfamiliar with JPL, I will give you a little history and background information.

JPL was a key player at the very outset of the space age more than a quarter-century ago. The Laboratory, then a research and development facility conducting guided missile work for the U.S. Army, had the opportunity to undertake the development of Explorer I, the first American satellite. Outfitted with Dr. James Van Allen's Geiger counters, Explorer I certified a technological revolution triggered only four months earlier by the USSR's Sputnik I. While taking the initial measurements in January 1958 that discovered the existence of the Earth's radiation belts, Explorer I laid the foundation for the scientific investigation of the universe. Before the year was out, President Eisenhower reassigned JPL to the newly-created National Aeronautics and Space Administration.

Relying strongly on its Army experience with guided missiles and the Explorer spacecraft, the Laboratory became the NASA center principally responsible for the scientific exploration of the moon and planets. The Ranger and Surveyor lunar projects, Mariner missions to Mars, Venus and Mercury, the Vikings to Mars, and the Voyager missions to Jupiter and Saturn are among JPL's most significant accomplishments.

Solar system exploration by the U.S. reached a peak of achievement with the Voyager 2 Saturn encounter in August 1981 and capped a decade which included two Mars landings, three Mars orbiting missions, a Venus lander and orbiter, three close passes by Mercury with the same spacecraft, four missions through the Jupiter system and three to Saturn. Some of these spacecraft still endure. Pioneer Venus continues to operate in orbit at Venus. Pioneers 10 and 11 and Voyager 1 are heading out of the solar system and any or all of them may determine the yet-unknown location where the sun's influence ends and true interstellar space begins. Three months from today Voyager 2 will reach its closest point to Uranus. Early next month, the spacecraft will begin its far encounter observations of the planet. If it continues to operate as well as now, Voyager 2 will investigate Neptune in 1989.

Our next flight mission at the Laboratory is Galileo, scheduled for launch next May and designed to conduct a comprehensive investigation of Jupiter and its satellites. The Galileo spacecraft is comprised of an instrumented probe to penetrate the planet's atmosphere and an orbiter to examine the Jovian system for two years. The remarkable results of the Voyagers at Jupiter and the capability of Galileo lead us to believe that this mission will be the most productive planetary science enterprise ever attempted.

At JPL, we have a staff of 5000, about 58% of which are engineers and scientists, a quarter of them with Ph.D. degrees. JPL is operated by the California Institute of Technology (Caltech) in Pasadena under contract to NASA, our primary and institutional sponsor. JPL functions as a NASA center but, as a part of Caltech, operates within the general framework of Caltech policies. I will later describe some important differences between us and the NASA civil service centers that arise from our Caltech connection. We are a "Federally Funded Research and Development Center" (FFRDC) as defined by the OMB's Office of Federal Procurement Policy in OFPP Policy Letter 84-1; we are in compliance with the letter and intent of this and related policies and laws designed to ensure that FFRDCs perform work appropriate to them and are not used to bypass the requirement for competitive procurement. The contractual agreement between NASA and Caltech defines JPL's mission and role in NASA and the conditions under which we may perform work for non-NASA agencies.

JPL is the principal NASA center for the scientific exploration of the solar system and has significant responsibilities as well in support of NASA's applications program including, for example, the recent Shuttle flight of our micro-gravity experiment; the astrophysics program, typified by the highly successful Infrared Astronomy Satellite (IRAS) mission; and the earth sciences program, which began for JPL with the productive 1978 Seasat Project. The major emphasis of JPL's part of the NASA program is the planning and execution of exploratory applications and scientific flight missions in Earth orbit and throughout the solar system. These flight mission assignments involve a broad range of hardware and software engineering, scientific analysis, and management effort. We also support activities involving the planning, research and development, implementation, and operation of NASA's worldwide Deep Space Network and other facilities, information systems appropriate to the conduct of flight mission operations and data analysis.

Our focus is the execution of large, complex tasks involving the development and application of advanced technology through organized project team efforts. The true test of our quality and competence is found in the success of our projects, whether done in-house or by contracting with industry. JPL is, at heart, a hands-on doing organization. To maintain our ability to perform successfully such projects it is essential that we periodically have the experience of designing and integrating advanced spacecraft and instruments in-house. Such hands-on experience helps us to be "smart buyers" from industry when that is most economical. Our competence depends critically on having both engineers and scientists with the full range of experience from mission conception to the analysis of project results.

JPL scientists provide their expertise to JPL-managed flight missions, to flight experiments of JPL and others, and to the support of NASA in planning and formulation of their science program for the study of the Earth, space, bodies of the solar system, and the universe. They also perform their own research in terrestrial, planetary and space sciences. JPL directs its its research efforts to provide special emphasis to complement areas where universities are not strong, or where it is essential to have in-house competence to provide leadership for instrument developments or to provide candidates for Project Scientist positions and related supporting roles. Typically JPL scientists team up with other scientists, primarily from universities, to propose space flight experiments on a NASA mission.

JPL's principal scientific interests are in the areas of Earth/Planetary Atmospheres and Geoscience, Oceanography, Planetary Astronomy, Fields and Particles, Solar Physics, Astrophysics, and Space Processing. About 400 work-years were applied to these areas in FY85 divided roughly equally between Principal Investigators, flight experiments, and supporting activities.

Frank B. McDonald, NASA's Chief Scientist, has described to your Task Force on October 4, 1985, how NASA manages scientific research and plans its scientific programs. JPL space scientists are not block funded and must obtain funding for their proposals in open competition with others in the community in a peer-reviewed process where final decisions are made by NASA Headquarters offices. We believe that the process is even-handed and results in the selection of the highest quality and most relevant proposals. It has the further advantage to us of providing an independent judgement of the quality of our scientific staff.

The quality, dedication, enthusiasm and innovativeness of our staff are the key to our success. By a number of measures, JPL compares very favorably in productivity with other NASA centers. For example, the NASA Technology Utilization Program publishes TECH BRIEFS, its primary outlet for announcing and disseminating information on the development of technical innovations by NASA centers' staffs and their contractors. Between 1982 and 1985, JPL accounted for 42% of all independently evaluated and published Tech Briefs. This is indicative of both innovativeness of our staff and support of the NASA program designed to get such information into the hands of U.S. industry. Being a part of Caltech helps us to maintain high standards and to attract and retain the high caliber people we need. Caltech administration and faculty committees regularly review our programs and, on an individual level, there is interaction in areas of common interest. Both Caltech and NASA support our active efforts to develop and maintain effective collaborations with the larger community of space scientists. Many of our leading scientists and engineers hold joint appointments at Caltech and other neighboring universities and colleges. For educators at all grade levels, JPL has developed, with Los Angeles County, a Math and Science Teaching Resource Center to assist with teacher training and to provide the most up-to-date resources in the space sciences.

It is difficult to quantify the effect of our overall program on the number of scientific and engineering personnel in the nation, but many students and graduates have told us how they were inspired in their career choices by, for example, the Viking Mars landings and the Voyagers' photographs of Jupiter.

NASA supports a JPL Director's Discretionary Fund which has strongly encouraged JPL collaboration with universities. In addition NASA cost-shares, with Caltech, the Caltech President's Fund, which is designed to encourage Caltech faculty and other university scientists in initiating collaborative efforts with JPL staff.

In November 1982 David Packard and three other members of the White House Science Council's Federal Laboratory Review Panel (the "Packard Panel") visited JPL as part of their examination of national labs and their future. I was pleased by their evaluation of our staff and with their recommendations designed to strengthen the Federal laboratories and their contribution to society. I will comment on two of their recommendations.

I agree that civil service R&D laboratories would benefit from being allowed more flexibility of their personnel and hiring policies. While JPL's average salaries for engineers and scientists are comparable to those of NASA civil service laboratories, we have the significant advantages of being able to offer higher starting salaries for outstanding new graduates and of having a broader allowable range of merit-based salary increases. We also have a special career path for researchers which reduces their temptation to switch to management assignments for career advancement.

I strongly endorse the Packard Panel's recommendations regarding increased discretionary funds to lab directors because my experience is that such funds would be very productively employed. JPL is unlike NASA civil service centers where much of the staff is supported by block-funded Research and Program

Management funds. Each JPL employee charges time to specific job numbers. While this arrangement is sometimes precarious, on balance I find that it works to our advantage by increasing our responsiveness to our sponsor and by providing clarity of purpose. An unfortunate aspect is that I, as Laboratory Director, have very limited ability to support seed efforts that I believe to be important.

NASA increased the discretionary funds to JPL over the years since 1969 to the present level of just under 0.5% of the R&D funds we receive. These discretionary funds have been effective in strengthening interactions with university faculty and graduate students, in encouraging publication, and in leading to important sponsored follow-on work. Our survey of past discretionary fund expenditures indicates that, while two-thirds of the effort has been directed toward advanced scientific and engineering investigations directly related to our NASA program, about one-third of the funds were applied to investigating the application of advanced technology to civil/non-space programs. In 1985, I applied DDF funds to strengthen our joint efforts with the University of Arizona in the detection and imaging of extra solar systems. Because of limited discretionary funds, which must support both JPL and collaborator (burdened) salaries in addition to the usual costs, we were able to support only one-fourth of the proposals submitted. I know there are worthy innovative ideas waiting to be explored if funding levels are increased.

NASA, through the contract and Memorandum of Understanding with Caltech, has recognized the obligation of JPL, as a major national laboratory, to serve society by helping to solve important national problems where our special capabilities can make a significant contribution. We meet this obligation by devoting part of our effort to defense and civil programs which complement our work for NASA. In FY'82, 22% of our staff was so

employed; in FY'85, 25%. During that interval there was a significant decline in our work for DOE, accompanied by a sharp rise in DOD-sponsored efforts emphasizing advanced technology work in areas where NASA support had weakened. I anticipate that the level of non-NASA work will not increase and that the mix of sponsorship will continue to be responsive to national priorities.

Getting back to JPL's primary role for NASA, I remain optimistic about the future of planetary science and about the research opportunities for working scientists and for young people beginning or preparing to begin their careers in the field. The decline that the program underwent a few years ago is behind us now. The Congress responded by increasing NASA's budget line items for research and analysis and for mission operations and data analysis which support the activities of many researchers, in addition to members of the various flight teams.

Further impetus to the planetary program came in the recommendations of the NASA Advisory Council's Solar System Exploration Committee (SSEC) in 1982 for a new set of planetary missions consistent with the scientific strategies of the Space Science Board and realistically reflecting the changing fiscal climate. The SSEC recommended setting strict priorities for prospective missions, adoption of lower cost, innovative approaches to their implementation, and the integration of the program's interrelated elements -- research, operations and missions — into a coherent whole.

SSEC's core program, which could be sustained at an annual budget level of $300-325 million (FY84 $), assigned highest priority to the Venus Radar Mapper (VRM) mission. VRM was approved for a project start in FY'84 and will be launched in 1988. A new class of low-cost missions using already-developed Earth orbital satellites as the carrier spacecraft

was recommended for future exploration of the inner planets. The Mars Observer is the first of this class to be approved and began development in FY 85 for a planned launch in 1990.

The final flight element of the core program is a new planetary-class spacecraft called Mariner Mark II, conceived as a simple, modular spacecraft to be designed in-house at moderate cost for missions beyond Mars. SSEC recommended a comet rendezvous mission as the first of the Mariner Mark II series. Both the comet rendezvous mission and the spacecraft design are in the final stages of pre-project development at JPL.

I believe that the NASA planetary program is scientifically valid, balanced and affordable. We at JPL support it and are in the process of implementing it.

In summary, JPL is a FFRDC, a national laboratory, a NASA center and a university operation. We have a record of accomplishment and a status of excellence. Our sponsoring agency, NASA, has specified clearly our mission. NASA administers JPL through a single contract with Caltech and insures our proper accountibility for government-provided funds. NASA conducts detailed, annual overall performance evaluations of our effort and requires response to any needs for correction. I believe we continue to make significant contributions to the nation in a cost effective operation which places particular emphasis on scientific and technical excellence.

DISCUSSION

Mr. WALGREN. Thank you very much, Dr. Allen.

Let me understand a little more about the personnel because this is new to me and I was sort of trying to listen and think of some other points you made at the same time.

Your people are not civil service. Is that right?

Dr. ALLEN. That is correct. All of our employees are employees of Caltech?

Mr. WALGREN. Are they university employees then?

Dr. ALLEN. Yes.

Mr. WALGREN. So, the laboratory is itself not an integral part of Caltech.

Dr. ALLEN. No; we are an integral part of Caltech.

Mr. WALGREN. An integral part?

Dr. ALLEN. Yes.

Mr. WALGREN. And there is a working arrangement between Caltech and NASA as far as its direction in which the research goes?

Dr. ALLEN. The contract is between NASA and Caltech.

Mr. WALGREN. I see.

Dr. ALLEN. I am the Director of JPL and vice president of Caltech.

Mr. WALGREN. I see. Can you elaborate a little more on the discretionary funds available to you? You said you had 0.5 percent, that it was up substantially from what it used to be. What did it used to be and what would you like to see in this area?

Dr. ALLEN. It used to be $1 million a year, and it was increased to $2 million, and this year to $3 million, for which I am very pleased. Those funds are used at my discretion through a peer review process which I conduct in the laboratory to permit, for example, new scientists who have not been able to be established in obtaining support for their work yet to be supported; to pursue particularly innovative ideas that arise during the year; and to undertake new directions which is where I feel the laboratory needs to develop its skills and competence. For example, we have been pursuing with some emphasis with these discretionary funds work in advanced microelectronic devices, work that is very compatible with certain research that goes on in the laboratory and will lead, I believe, to substantially improved instrumentation capabilities for future NASA space missions.

Now, there is an additional fund which NASA provides to the president of Caltech which is a matching fund. That is, NASA provides some funds and Caltech provides funds. That is used primarily for campus research which will, in one way or another, involve JPL.

Mr. WALGREN. But the base fund you have is 0.5 percent of the total research?

Dr. ALLEN. Yes; our budget in fiscal 1985 closed out the year at about $650 million. I am provided for next year $3 million.

Mr. WALGREN. Can you compare that with any other laboratories?

Dr. ALLEN. Yes; I think Los Alamos and Livermore, for example, under DOE policies, end up with a portion of their basic programmatic activity, and I think that portion is on the order of 10 per-

cent which is available to the laboratory director for discretionary work.

Now, one needs to be careful about this term discretionary. For example, those funds at Los Alamos and Livermore are available clearly for work that is associated with the programs. It is audited and reviewed and judged by DOE, but it is not subject to prior detailed approval. DOE has a very nice arrangement with those laboratories to avoid prior micromanagement of these activities, and the laboratory director has a substantially greater sense of responsibility for what his scientists are doing in pursuing new activities than I feel that I do under the more limited discretionary funding arrangement.

Mr. WALGREN. Thank you. Let me recognize Mr. Lundine.

Mr. LUNDINE. This is a fascinating example of a partially Government-partially private operated laboratory. From your experience, would you think it would be advantageous if other laboratories were converted to Government owned, contractor operated?

Dr. ALLEN. I find that a very difficult question, because it turns out that almost all of the FFRDC's under this mode were created many years ago. One has the handicap of realizing it has worked well but not being quite sure as to the extent to which that should be started again.

For example, with regard to Los Alamos and Livermore, there is no question that the University of California management of those two laboratories has been, and continues to be, of great benefit to the country. But it would be very surprising if the University of California would undertake those arrangements if one asked that question now.

However, I do believe the record of these arrangements of the ones that I am most familiar with, Los Alamos, Livermore, JPL, the Applied Physics Laboratory at Johns Hopkins, and a few others, have been successful. Therefore, they represent a model that is worthy of careful consideration in the future.

Mr. LUNDINE. Your testimony indicated that NASA's discretionary funds to JPL are just under 0.5 percent of the R&D funds received. I think you testified also here this morning that Caltech professors serve as evaluators in part as to your work. What mechanisms do you have in place to evaluate the effectiveness of those funds expended?

Dr. ALLEN. I am required to report to NASA headquarters annually on the use of those funds and to report in detail on the work that was accomplished and the people who did it. So, that work is evaluated by NASA after the fact.

Mr. LUNDINE. And do you have any other internal evaluation?

Dr. ALLEN. Oh, yes; we have an internal peer review system which selects the work in the first place. My chief scientist happens to be in the hearing room this morning, and he leads the peer review activity which selects the projects which we will do under that discretionary account and judges their progress during the year.

Mr. LUNDINE. Thank you. Thank you, Mr. Chairman.

Mr. WALGREN. What is the greatest benefit of operating in the model or mode of your relationship with the university and the contractor that you would cite?

Dr. ALLEN. Well, there are certainly several. The first is a more flexible personnel policy, that is, the ability to hire, discharge, and pay salaries in accordance with the needs.

The second one is an ability to do contracting in a manner which, while it meets the formal requirements of the Government; that is, we do not take shortcuts in terms of procedures, is nevertheless free of many of the time consuming bureaucratic processes associated with the contracting. So, our research contracting can be done, I believe, more effectively and more speedily than at NASA headquarters without any loss in the rigor of the process.

The third is that there is no question in my mind that the intimate association with the Caltech campus provides an assurance of quality control and scientific excellence which I think has been reflected over the years in the performance of JPL.

Mr. WALGREN. Mr. Fawell?

Mr. FAWELL. Thank you. I apologize for not being here sooner.

Let me ask this question. You had indicated that you thought the University of California, if it were to be asked now to undertake its contractual obligations in operating Los Alamos or Livermore, would not do so as it did. Apparently, that is a long operation by the University of California. Why do you say that?

Dr. ALLEN. The University of California is required each 5 years to evaluate and then renew the contract. They have just gone through that process again here in recent months and decided to renew it.

However, if one looks at the discussions that go on within the University of California board of regents and the faculty and the leadership of the University as they discuss that, it seems clear to me that they regard this as an anomaly and a distraction from the fundamental purposes of research and teaching at the University and one which, if the history were not what it is, they would probably not undertake. However, the history is what it is, and the University has contributed to the security of the country in that management. Therefore, they continue to accept the responsibility of that stewardship.

Mr. FAWELL. Would you say that would be the same reaction, say, of the University of Chicago in reference to Argonne?

Dr. ALLEN. I am not really qualified to judge on Argonne.

Mr. FAWELL. How would you explain the difference between the arrangement, say, of the University of Chicago or, if you are not familiar with that, the University of California and its operations of Los Alamos and JPL? What is the difference?

Dr. ALLEN. In principle, they are quite similar. That is, the way the contractual arrangements are made and the responsibilities are quite similar.

The differences, of course, are really more in the practice. First of all, there is geography. We are 5 miles or thereabouts from the campus, whereas Los Alamos is a lot farther away from Berkeley.

The second one is that we do only a small portion of classified work which is segregated on the laboratory grounds and the laboratory, in general, is kept open since most of the work being for NASA is unclassified and is intended to be fully open to university researchers and students. Therefore, we work hard to ensure that what little classified work we do doesn't impede on that.

Clearly, Los Alamos and Livermore have greater restrictions, and it works the other way around. The university seeks to find mechanisms for university researchers to interact outside the fence, if you like, but with the scientists inside the fence.

So, those differences do restrict seriously the interactions between the university researchers at the campuses of the University of California and the two laboratories whereas they do not at JPL, and that interaction is far more active.

Mr. FAWELL. Thank you.

Mr. WALGREN. Thank you, Mr. Fawell.

You mentioned with respect to personnel and personnel policies and relationships that the salaries were comparable to——

Dr. ALLEN. The average salaries of scientists and engineers at JPL is almost exactly the same, according to a survey which NASA did recently, as the average salary of scientists and engineers at a NASA civil service center.

Mr. WALGREN. Are they directly comparable also to the Caltech salaries?

Dr. ALLEN. The campus salaries?

Mr. WALGREN. Yes.

Dr. ALLEN. That is a harder comparison to make, because in general the campus, of course, consists of faculty with tenure and salaries that are associated with tenured faculty. Therefore, our salaries tend to be more compared with the staff members on the campus who are smaller in number and tend to be more temporary in employment, that is, research associates and the like. So, in general, No. 1, we are required by the policies of comparability, that is, our salary structure at JPL is freed from certain detailed reviews by the OPM because we maintain a comparability between our salaries and the staff salaries at Caltech, but there are some differences.

Mr. WALGREN. What about turnover and discharge experience? Can you compare those with other Government laboratories—Government-owned laboratories like Oak Ridge or something like that?

Dr. ALLEN. Yes, and I think all of these numbers are more or less comparable, including those of the civil service centers. That is, even though I make this point that our employees do not have either tenure or any assured employment due to the nature of the contractual relationship, in fact, the turnover is fairly small. It runs in the 7- or 8-percent kind of range on the average. Some years, of course, if there is a decrease in the budget, it will be greater.

That number is, I think, more or less the same as the civil service centers and is about the same as the other FFRDC's operated by universities I am aware of. So, the two points that I really would like to emphasize to you from that is that the protectionist aspects of the civil service and the inhibitions on the salary structure in the civil service, in the final analysis, don't do much constructively, but they inhibit the system very greatly.

Our employees do not have protection, but they don't go out at a much higher rate than they do at a civil service center. We do not have constraints on our salaries in the same way at all, yet the average salary is not appreciably higher. So, it is clearly possible to have the same economies, the same low turnover rate at civil serv-

ice centers if one simply is granted the flexibility from the civil service system.

NASA is proposing such things at its civil service centers at the present time in accordance with initiatives that it is working out with the Office of Management and Budget as part of a project to improve productivity at the centers. I think these initiatives will be helpful to NASA.

Mr. WALGREN. Do you have any apprehension about Federal laboratories occupying a field that would be better reserved for universities in the research that they do in the institution itself?

Dr. ALLEN. Yes, sir. I think that is an important point and one that has to be guarded against all of the time. We take a great deal of care of that at JPL. We understand the policy in that matter quite well, and we recognize the need to ensure that we do not engage in inappropriate competition with universities. The policy is that the science research on the NASA missions will be done by university scientists.

It is necessary that we have scientific capability at JPL and that it needs to be an excellent capability, but it is to be limited. It is limited in those areas where universities may not be able to provide the competence—fields that are new or developing that have not developed in a university. We need certain project scientists to work intimately with the spacecraft designers, and they need to be in-house, and so on. There are a few of these requirements which we must have.

As I indicated, those few that we must have still must compete in the peer review process which NASA headquarters runs for their support.

Mr. WALGREN. There is a specific policy that the research shall be done by university scientists. Is that right?

Dr. ALLEN. Yes. That is correct.

Mr. WALGREN. That same policy wouldn't apply to other laboratories. Is it possible to generalize about how a Federal laboratory can not invade what might be agreed upon as a university role? I don't know whether I could define a university role for you, but aside from implementing apparently a direction that was developed whole cloth for JPL, thinking of Federal laboratories, Federal science effort more broadly, can you warn us to be limited in what we do within the Federal laboratories? Are there down-sides to that? Is there an overreaching tendency to want to expand into areas that would better be left to universities?

Dr. ALLEN. Yes, I think there is such a tendency. I think it simply must be guarded against at all times. It is hard to generalize. Again, going to Los Alamos and Livermore, you can't move that research, for the most part, out of Los Alamos and Livermore for classification reasons, and for the very highly specialized character of certain aspects of the research.

Nevertheless, the Government policy overall is that the basic research of the country should, in the overwhelming majority, be performed in the universities of the country, on the campuses of the universities, and that the places where the Federal Government does that at a Federal laboratory should be considered exceptions to that.

There are a number of required and appropriate exceptions, but they need to be monitored and ensure that they do not exceed what is, I think, a sound fundamental policy that basic research should be performed at the universities.

Mr. WALGREN. But the Federal laboratories are having to get into this more and more in that—my only measuring point would be the Bureau of Standards where we had obviously a solid function that had to be fully developed but were doing basic research which could also be done in universities. Yet, if we don't continue to have the complete function there, we would be missing something at some point.

Dr. ALLEN. Of course. There are good reasons for doing basic research in Government laboratories, but the policy should be that those reasons should be implemented with a notion that they should be minimum.

Mr. WALGREN. Mr. Packard?

Mr. PACKARD. Thank you, Mr. Chairman.

Do you think that other laboratories ought to operate more as a Government-oriented operation as yours is, or do you believe that you have specific assignments and characteristics that would justify having yours operate differently than most of the other national labs?

Dr. ALLEN. Again, I find it somewhat difficult to generalize, and I think the operation of JPL has been a very good one for the Government. If the situation arose where a similar appropriate circumstance could be implemented, then clearly I think that would be the best thing to do. I think there are significant advantages in the JPL kind of operation as compared with the civil service kind of operation.

Mr. PACKARD. Are there some disadvantages? Do you find some difficulty with JPL the way it is operating that you wish could be rectified?

Dr. ALLEN. My job is to rectify the difficulties at JPL, so certainly I work on that all the time. But those that are associated with its not being a civil service organization?

Mr. PACKARD. That is what I meant.

Dr. ALLEN. I am hard pressed to think of any. It is clear that from time to time, a non-Government employee, in the execution of the planning and the formulation of policy for a government body, is treated somewhat differently. That is, JPL, on occasion, is viewed by NASA headquarters as being somewhat different than their civil service employees.

In fact, that is minimal. JPL in the planning processes, in the different bureaucratic action processes of NASA headquarters, is treated in by far the majority of the cases equivalently with the civil service centers. Perhaps if all the other centers were not civil service centers, that would pose an awkwardness in that civil servants clearly have a preferred relationship in the executive branch for the execution of policies and contractual arrangements.

So, again, I find it hard to say that all centers should be operated out of the civil service mode. I guess the conclusion I come to is a little bit different, and the point I have been trying to make is that I think JPL proves that the inhibitions inherent in the civil service system and the bureaucratic constraints on the research contract-

ing process are not necessary, and that there is no reason why one couldn't have the flexibility and the responsiveness in the civil service laboratories that one can have at JPL by simply granting flexibilities with an assurance that the JPL operation provides that one will not lose control of the contractual operation nor see salaries escalate out of bounds.

Mr. PACKARD. I have no further questions. Thank you.

Mr. WALGREN. Thank you, Mr. Packard.

Mr. Lujan?

Mr. LUJAN. Thank you.

DOE runs all their laboratories on a GOCO basis, don't they?

Dr. ALLEN. As far as I know, yes, sir.

Mr. LUJAN. I can't think of any right off that aren't, and that has worked pretty well.

Dr. ALLEN. Yes, sir.

Mr. LUJAN. Yesterday's meeting brought out the fact that the GOCO's, at least in my estimation, were established to get away from all the civil service requirements of people having their tenure and moving people in and out as the needs changed. That was pointed out as one of the shortcomings of the civil service system.

You have had experience both in and out of the Government and the GOCO's. Do you think that we need to make some changes in the civil service system to be able to bring people in and out quickly into managerial positions? It was suggested, for example, that we set up some kind of a classification of maybe 3 years that somebody could be brought in without all the hassle of being nominated and having to put up with all the regulations. Do you think that would be beneficial?

Dr. ALLEN. Yes; I believe there are a number of changes which are needed in the civil service system for the purposes of research operations. NASA is in the process of formulating a set of those as a major initiative with the Office of Management and Budget, and they include the feature that you just mentioned.

Mr. LUJAN. In practice, does it happen that people move in and out of JPL, Livermore, all the different ones, or generally once somebody gets into one of those organizations is it a lifetime position, or do you change because of the changing needs?

Dr. ALLEN. The answer to that——

Mr. LUJAN. I mean, what is your turnover rate?

Dr. ALLEN. Our turnover rate is low, and JPL has, as a matter of fact, a number of employees who have been there for a very long time, as do Los Alamos and Livermore.

I really think that the point is that having that flexibility, having the nontenured, the nonassurance of employment, having to respond to fluctuating budget levels as these laboratories do, has not historically provided a churning situation at all. It has provided a stable environment.

But the flexibility, the knowledge of the employee that he can be removed, or transferred, or moved, or whatever at the management's decision if the needs require it is a fundamental difference. The attitudes are different. I believe the ability to keep qualified people there and to attract qualified people is fundamentally differ-

ent under that kind of an arrangement even though, in fact, the salaries are not higher nor is the turnover greater.

Mr. LUJAN. The actual practice—at least I keep very close track of Sandia and Los Alamos because those are my constituents and I don't want to see the employment level fluctuating—in actual practice, the GOCO's don't have very much fluctuation in funding levels, do they? Does JPL or is it pretty constant with maybe a little 5 or——

Dr. ALLEN. No, no; JPL has had more fluctuations than have Los Alamos and Livermore. We are a different kind of a laboratory in that we are more engineering oriented where Los Alamos is highly physics oriented, and we are funded to execute particular programs. So, our funding does fluctuate with the approval of a given program. For instance, our biggest on-going program now is Galileo to Jupiter. That is at a peak funding and a peak of personnel. So, we do have more fluctuations than do Los Alamos and Livermore.

There is a second situation with regard to JPL that is different than Los Alamos, and that is it is my judgment that JPL should not grow. There are several reasons for that. One is the small size of Caltech and, therefore, that places a constraint. The second reason is a geographic one. We really don't have much room to grow, and I don't think we should expand into other geographic locations.

Los Alamos has had a fairly steady growth over the years which is, as far as I can see, still continuing. So, there are those kind of differences. We have constraints on our employment, No. 1, and, No. 2, we fluctuate more than Los Alamos and Livermore. We have gone through periods where we have reduced the staff by a reasonable amount, amounts on the order of 10 percent. So, that is a difference.

But we can do it effectively, without loss of morale, and respond well to the needs of the Government under the flexibilities that we have.

Mr. LUJAN. Does Caltech leave you pretty much alone to run your show?

Dr. ALLEN. No.

Mr. LUJAN. As the director I would imagine—some directors have said we either like this or we don't like this because they collect their percentage and we do our thing——

Dr. ALLEN. No; there is a very significant distinction between Los Alamos and JPL with regard to the university.

Mr. LUJAN. I wasn't singling out Los Alamos. I don't want to say that one of their directors told me that. They have not, but directors in different Government laboratories have expressed that preference.

Dr. ALLEN. Over the years, the University of California has had a very modest influence, and appropriately so, on the management practices at Los Alamos. At JPL, the arrangement is substantially more intimate, due to proximity, due to the unclassified nature of the work at JPL, and just due to the tradition of the laboratory.

For instance, I am the first laboratory director who has not been a faculty member of longstanding at Caltech. We have a great many interactive appointments of one kind or another between the campus and the laboratory.

Mr. LUJAN. Do you mean in cooperative programs rather than in operating the whole facility?

Dr. ALLEN. Well, not in operating, I think, but cooperative of a number of kinds. For example, the principal investigator, the project scientist, on the Voyager mission is a Caltech professor. The principal investigator on the camera for the Hubble Space Telescope is a Caltech professor. So, there are a lot of those kinds of interactions which are very close. The chief scientist, at various times, has been a Caltech professor.

So, we have many very close interactive appointments, interactive arrangements. I participate in the management processes on the campus, and there are faculty committees that review various aspects of the work at the laboratory.

Mr. LUJAN. If you got some direction, of course, from the faculty committee, your responsiveness must be to NASA. Is that not correct? Rather than to Caltech?

Dr. ALLEN. The contract is clearly between NASA and Caltech. It is between NASA and Caltech. It is not JPL; it is Caltech. Therefore, it is clearly necessary for me to be responsive to both the direction of NASA and the policies of Caltech.

When those come into conflict, there can be an issue. There are issues of very small character that arise all the time. In some of the legal areas, for example, there are little differences in the procedures which NASA might like to see us follow and those which Caltech follows, and those are ironed out by negotiation.

Sometimes, these interactions are not all that pleasant. A faculty is not the most straightforward organization in the world to deal with. Therefore, sometimes the faculty expresses opinions about the work at JPL which I don't particulary like and don't agree with, but nevertheless, I think that arrangement, on balance, is a healthy one. It is a vibrant one, and it provides challenges to make it work smoothly.

Mr. LUJAN. With your long experience—just to sum up the thrust of the question—is it more advantageous or detrimental to have a GOCO type operation as opposed to a direct employee operation? If you had to do it one way or the other, which would you prefer? Where can the best results be obtained?

Dr. ALLEN. The university-operated laboratory.

Mr. LUJAN. Thank you, Mr. Chairman.

Dr. ALLEN. By the way, Mr. Lujan, just for your interest, I served a tour at Los Alamos. I am presently on the scientific and academic advisory committee to President Gardner for Los Alamos and Livermore, so I visit there periodically and have a great admiration for that laboratory. And I like to compare JPL with Los Alamos. I don't mean that in a——

Mr. LUJAN. Well, it would be more comparable with Sandia. It is more engineering-oriented.

Dr. ALLEN. It is perhaps a little more comparable with Sandia, but nevertheless, because I both admire and appreciate the work at Los Alamos, I find that Los Alamos and Livermore provide a certain set of standards which I think is useful to keep weighing the operations at JPL against and vice versa. I take to them suggestions now and then of the things that we do that they might emulate.

Mr. LUJAN. Thank you.

Mr. WALGREN. On behalf of the Task Force, we certainly do appreciate your being a resource to us, Dr. Allen. Thank you.

Dr. ALLEN. It is a pleasure to be here.

PANEL: REGULATION-DRIVEN RESEARCH

Mr. WALGREN. The next group of witnesses have been asked to discuss regulation driven research with us. This panel includes Dr. Joe Hendrie, Dr. Bernard Goldstein, and Thomas Jorling.

Dr. Hendrie is, by way of introduction, with the Brookhaven National Laboratory and is a former Commissioner of the Nuclear Regulatory Commission. Dr. Goldstein is a former Assistant Administrator of the U.S. Environmental Protection Agency and is presently Chairman of the Department of Environmental and Community Medicine at Rutgers Medical School. Mr. Jorling is also a former EPA Assistant Administrator for Water and Hazardous Materials and is presently a professor of environmental studies at Williams College.

Gentlemen, welcome to our discussion. Written statements will be incorporated in the record fully. Please feel free to underscore those points you feel you would like to emphasize and communicate them in whatever way you feel most effective.

Why don't we start and go through all your testimony, one after the other, and then we will come back for some discussion. In the order in which I introduced you, we will start with Dr. Hendrie.

STATEMENT OF DR. JOSEPH M. HENDRIE, BROOKHAVEN NATIONAL LABORATORY, LONG ISLAND, NY; AND FORMER COMMISSIONER, U.S. NUCLEAR REGULATORY COMMISSION

Dr. HENDRIE. Thank you very much, Mr. Chairman. It is an interesting experience to come back to the Halls of Congress and to see you all, but it is also a pleasure to find myself in this somewhat more congenial theater than has been the case.

Mr. WALGREN. I was going to say you are a lot more relaxed than your old Nuclear Regulatory Commission days.

Dr. HENDRIE. True enough, Mr. Walgren.

There were four questions addressed to this panel on regulatory directed research. The first was, "Should regulatory agencies maintain R&D programs or should their R&D be conducted by another agency or agencies? In other words, does it matter where in the bureaucracy regulation—related research lies?"

My answer is that it does, and it makes a lot of difference. The regulatory agency has to have control of the content and the schedule and the budget of the research if that research is to be responsive to the needs of the agency. It does matter where in the bureaucracy the control lies. If it is not with the regulatory research, the research will sooner or later wander away from those regulatory needs.

In my experience, it is no easy job to keep the researchers and their agency program officers pointed in the right direction, even when those program officers are in the same agency and the research is in effect controlled by the same agency. If the researchers

and the program officers report to a different agency, you sort of lose any hope of keeping them on track.

It is not that researchers and program officers are maliciously intended, you understand, but the research always opens fascinating new avenues on either side of the scheduled path—research opportunities that had not been suspected when scheduled work was started—and if the researchers and the program officers too are worth a tinker's damn, they will want to follow those avenues.

In a good regulatory research program, of course, there is flexibility provided so that some of those new avenues can be followed. But the agency managers have to watch out and see that the main effort doesn't suffer. That careful monitoring is not practical if the research program control is in another agency.

The other agency's program officers, soon or later, will convince themselves that they know better than the regulators what the regulators need, and then the research will begin to wander off the path, and the poor regulators will be left sending ineffectual memoranda of complaint and their information needs will go unattended.

The second question that was posed to the panel is, "How should regulatory agencies maintain quality science in the face of regulatory deadlines?"

My answer is, keep the science and the deadline separated. There is a basic incompatibility between science and regulatory work. Regulatory work is focused on the present—today's problems. It has a time horizon that is rarely longer than a month or two. Research takes several months just to define the technical areas that you are going to think about and move forward into research. So, research time horizons are years.

The solution is to contract the actual research to organizations that specialize in it. In the regulatory agency, you look for people who have a bent for science and good technical credentials and you put them in a research management section. You separate that section from the day-to-day crises and problems that the licensing and regulating people are dealing with. These people in the research management section then become the contracting agencies and program officers for the various programs of research that are contracted out to universities, Government and private research labs, scientific and technical organizations, and anybody else who may have the competence to deal with a particular area.

That separates the science from the regulatory deadlines and keeps them from confusing one another. The research management section in the agency and the individual program officers become an isolation device. They translate the regulatory issues into scientific and technical objectives that the researchers can address. At the other end of the work, they ought to interpret the research results in terms of regulatory needs.

The advantages of this system are considerable. In the first place, the agency gets much more scientific bang for the buck. It can place a given piece of work with an organization that specializes in that area, has unique facilities, perhaps world leaders in the research in that area. The agency thus piggy-backs on other and ongoing research in that area at that particular organization and benefits from a quality of people and the quality of equipment that the agency could not possibly have afforded as an in-house effort.

Second, the system keeps the research-types doing research and the regulator-types doing regulatory work. As a general rule, people with the right temperament for one don't do very well in the other.

Finally, the system creates a community of very smart people in the universities, in the laboratories, and in the research organizations who are knowledgeable about the regulatory agency's missions and programs. Those scientists and engineers are then a major resource for the agency. They can provide advice and reviews on assorted scientific and technical matters crucial to the agency, and they give the agency ready access to the larger community of scientists and engineers around the world.

The third question had to do with how a regulatory agency should translate questions framed by nonscientists into scientific questions that research can address.

The answer is that that is the job of the research management section in the regulatory agency. Sometimes, the translation is pretty easy because, at least in safety regulation, you find that the people in the licensing and regulatory staffs generally have good technical backgrounds and will understand the way in which to phrase the questions.

The hard problems come when you have to deal with a lay person who simply doesn't have the background to understand what sorts of things can be measured and answered in a well-defined way, and then the problem of the translation of the question into a research objective becomes more difficult and becomes an iterative process in which you have to go back and in part educate the questioner and in part iterate his question into a form so that it can be translated into a research objective.

Asking the right question, that is, getting the scientific and technical objectives of a piece of research correctly defined, is about half the battle. A diffuse or inaccurate definition will almost certainly lead to a diffuse or inaccurate result from the research in terms of the regulatory need. Sometimes, it may be necessary to do a not insubstantial piece of research in order to understand what the question really should be.

Mr. Chairman, the last question was, "How are scientific research results best translated into the regulatory arms of the agency?" The answer is with difficulty.

In my experience, it is not easy to get the regulatory-types to use the results of the research which not so long ago they were complaining desperately they needed. The reason is pretty clear.

The regulatory and licensing people live literally on a day-to-day basis. The problem comes up in a technical area. They need an answer. They complain that they don't have the answer. That starts the research program generation process going. But it may be years before the answer comes back out of the research. In the meantime, the regulatory and licensing people have to live this afternoon and tomorrow and next Monday. So, they have to go ahead and devise some solution, and it generally involves a very conservative interpretation that gets around the particular technical problem by, in effect, overshooting on the safety requirements.

Then, by the time the research comes back, the regulatory people have long since forgotten that this was a desperate issue with

them. They had this problem but it was a long time ago and the situation has moved on to a lot of other things in the meantime, and they are a little reluctant to go back in and dig up this thing which is not bothering them today or this afternoon or tomorrow and introduce the research results and readjust the regulatory requirements and integrate it into the general regulatory patter.

So, you can understand very well why there is a reluctance to incorporate the results of research. The answer just is that the agency management needs to be very firm and insist that new results on a consistent and orderly basis be introduced into the requirements.

That is essentially all I wanted to say, Mr. Chairman, except to note finally that it is a pleasure to find a panel of the Congress that isn't asking the question "Why does a regulatory agency need to do research at all?" It is real pleasure to find a group in the Congress and their staff who understand the answer to that question well enough so it doesn't even need to be on the list.

Thank you.

Mr. WALGREN. Even if they are lay people.

Dr. HENDRIE. Even if they are lay people. Well, I think you have heard enough about science and technology in the years on this committee so that all of you qualify for something considerably better than lay people.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Hendrie follows:]

TESTIMONY OF

JOSEPH M. HENDRIE

Brookhaven National Laboratory
Upton, N.Y. 11973

before the

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

at a hearing on

"Science in the Mission Agencies and Federal Laboratories"

October 24, 1985

Mr. Chairman, I commend you for holding this series of hearings on "Science in the Mission Agencies and Federal Laboratories." You have posed a number of searching questions to the many witnesses who have appeared here. I think the record of these hearings will be a most valuable reference source for policy decisions on research for a long time to come. I am pleased to have a part in these hearings and to have the opportunity today to offer a few remarks on research in the regulatory agencies.

I had better make clear at the beginning my background and prejudices. I have been a staff member at Brookhaven National Laboratory off and on for 30 years. I have a high regard for Brookhaven, and for the other National Laboratories in the Department of Energy system. In the years when I was away from Brookhaven, I worked for the Federal Government in the area of nuclear regulation. I served with the Atomic Energy Commission's regulatory staff in 1972-74 and on the Nuclear Regulatory Commission in 1977-81. Since returning to Brookhaven in 1981, I have been on a part-time basis, with the balance of my time devoted to my consulting practice. In that practice, my clients are utilities with nuclear plants. I have a lot of experience with science in nuclear regulation, as a

researcher, as a regulator, and through my current clients, as one of the regulated. My views are inevitably shaped by that experience, and by my firm belief that the NRC safety research program has been an outstanding success.

Mr. Chairman, you suggested four questions to this panel. The first is "Should regulatory agencies maintain R&D programs, or should their R&D be conducted by another agency or agencies? In other words, does it matter where in the bureaucracy regulation-related research lies?"

My answer is that for the safety-regulating agencies, at least, it is essential that they have R&D programs that they control. The regulatory agency need not carry out the research with its own personnel and, in fact, it should not, but control of the content, schedule, and budget of the research must rest with the agency if it is to be responsive to the needs and priorities of the agency. It does matter where in the bureaucracy the control over the research lies: if it is not with the regulatory agency, the research will sooner or later wander away from the regulators' needs.

In my experience, it is no easy job to keep the researchers and their agency program officers pointed in the right direction even when those program officers are in the same agency as the licensing and regulating staff. If the researchers and program officers reported to a different agency, there would be no hope of keeping them on track. It is not that researchers and program officers intend to go in other directions, but that the research always opens fascinating new avenues of investigation on either side of the scheduled path, research opprotunities that had not been suspected when the scheduled work was started. If the researchers, and the program officers too, are worth a tinker's dam as scientists, they will be unable to resist these new avenues.

In a good regulatory research program, there is some flexibility provided so that some of these new avenues can be followed. But the agency managers have

to keep careful watch to see that the main effort, the scheduled work, does not suffer. That careful monitoring is not practical if the research program control is in another agency. The other agency's program officers will convince themselves over time that they know what the regulators need better than the regulators do. Then the regulators are left sending ineffectual memoranda of complaint and their information needs go unattended.

Your second question, Mr. Chairman, is "How should regulatory agencies maintain quality science in the face of regulatory deadlines?"

My answer is that you have to keep the science and the deadlines separated. There is a basic incompatibility between science and regulatory work. Regulatory work is focused on the present, today's problems, with a time horizon rarely longer than several months. Research needs several months just to define the technical and scientific questions to be addressed; research time horizons are several years and often more.

The solution is to contract the actual research to organizations that specialize in research. In the regulatory agency, one finds (or recruits) some people with good scientific and technical credentials and an inclination toward research. These people are put in a research management section and are separated from the day-to-day crises and problems of the licensing and regulating sections. They become the contracting agents and program officers for the various programs of research that are contracted out to universities, government and private research laboratories, and scientific and technical organizations.

That separates the science and the regulatory deadlines and keeps them from confusing one another. The research management section in the agency and the individual program officers are the isolation device. They translate the regulatory issues into scientific and technical objectives that can be understood and addressed by the research organizations. At the other end of the work, they

interpret the research results in terms of the regulatory needs.

The advantages of this system are considerable. In the first place, the agency gets much more scientific "bang" for its buck. It can place a given piece of research with an organization that specializes in that kind of work, has unique research facilities, and world leaders in the area. The agency thus "piggy-backs" on other and on-going research in that area at the particular organization and benefits from research people and equipment that the agency could not possibly have afforded as an in-house effort.

Second, this system keeps the research-type people doing research and the regulator-type people regulating. Most top-flight research people simply don't have the temperments for licensing and regulatory work. And most people who can sustain and even enjoy the crisis atmosphere, the do-everything-yesterday pressures, and the sheer abuse of regulatory work simply don't make good research people.

Finally, the system creates a community of very smart people in the universities and laboratories and research organizations who are knowledgeable about the agency's mission and program. Those scientists and engineers are a major resource for the agency. They can provide advice and reviews on assorted scientific and technical matters crucial to the agency, and they give the agency ready access to the larger community of scientists and engineers around the world. On occasion, the odd researcher may even develop a taste for regulatory work and join the agency.

Your third question, Mr. Chairman, is "How should a regulatory agency translate questions framed by non-scientists into scientific questions that research can address?"

My answer is: Give the job to the agency's research management section. It is what they are supposed to be good at doing. Sometimes the translation will not

be too hard, especially if the question originates with the regulatory staff. The regulatory people in the agency may not be research scientists but they are familiar with the scientific and technical issues they have to deal with and most of them will have scientific or technical educations. So the regulators will tend to form their requests for information in a way that makes translation into research objectives relatively easy--most of the time. Questions from lay persons, Members of Congress, for instance, are often very hard to translate into scientific terms because there is no comprehension on the questioner's part of what sorts of things can be answered in a well-defined and quantitative way. To deal with one of those questions, one has to educate the questioner and redefine his question to one that can be answered. I have not, by the way, had any notable success with that process with the Members of Congress.

Asking the right question, that is, getting the scientific and technical objectives of a piece of research correctly defined, is often half the battle. A diffuse or inaccurate definition will almost certainly lead to a diffuse or inaccurate result from the research. Sometimes, it may be necessary to do some research to see what the question should be.

Mr. Chairman, your last question is "How are scientific research results best translated into the regulatory arms of the agency?"

With a large club is the answer I am tempted to give. In my experience, it is not easy to get the regulatory side of the agency to accept and use the research results it so eagerly sought a few years before. Perhaps that is the key to the paradox. The regulators needed some information desperately for an issue that had arisen. They called to the research side, which went to work and had the research carried out. Now the result is in hand, but it is three years later. The regulators had to find some solution to the issue and they didn't have three years. So they mandated some grossly conservative requirement and went on with

their business. From their standpoint, the issue is settled and there is some reluctance to make an active issue of it again by changing the requirements. Of course, if the research indicates something additional is required for safety, then the matter will move. But if it is just to relieve a too-conservative requirement, it does not have much momentum. Besides, the regulators will tell you, they feel very comfortable with the additional margin that conservative interim requirement provides.

A better answer is that the research management section needs to put the research results in a form directly applicable to regulatory staff positions or to agency regulations and rules, and agency management needs to be very firm and insist that the new results be incorporated in current regulatory practice.

Mr. Chairman, before I close these remarks I would like to note an interesting aspect of your question list on science in the regulatory agencies. And that is that your list did not start with the question "Why does a regulatory agency need to do research?" I got pretty tired of trying to answer that question during my time on the Nuclear Regulatory Commission and I understand the oversight and appropriations subcommittees for the agency are still asking it. It is a real pleasure to talk to a committee of the Congress where there is some understanding of the key role that research plays in safety regulation.

Mr. Chairman, I thank you and the Committee on Science and Technology for this apportunity to testify today, and I wish you well in this review of Federal science policy.

Mr. WALGREN. Thank you.

Dr. Goldstein?

Mr. LUJAN. One of the nice things in your written statement was that you never had any trouble with Members of Congress trying to explain what you were up to.

Mr. WALGREN. Dr. Goldstein?

STATEMENT OF DR. BERNARD D. GOLDSTEIN, PROFESSOR AND CHAIRMAN, DEPARTMENT OF ENVIRONMENTAL AND COMMUNITY MEDICINE, UMDNJ-RUTGERS MEDICAL SCHOOL, BUSCH CAMPUS; AND FORMER ASSISTANT ADMINISTRATOR FOR RESEARCH AND DEVELOPMENT, U.S. ENVIRONMENTAL PROTECTION AGENCY

Dr. GOLDSTEIN. Thank you. I, too, appreciate the opportunity to come back here, if you will, more as a philosopher than as a supplicant. It is a much more relaxed approach.

And I do thank the members of the committee for, in a sense, feeling that this is an important enough issue for them to devote their limited time. This is something that speaks very well for the possibility of dealing with these important problems having to do with the control of where is really the best place to do regulatory-related research and how is the best way to do it. Again, as Dr. Hendrie said, I am glad we are past the question of whether it should be done. It clearly should be done.

I am an experimental scientists by training and have in fact returned in part to be able to do some more experimental science. One of the things that one does as an experimental scientist when asked a question is to look and see whether someone has done the experiment already. I think, in a sense, the Federal Government has, in terms of looking at whether or not research should be done in a regulatory agency or should be done in a science based Federal agency.

I think that experiment is, if you will, the comparison or contrast between EPA and OSHA. These are both regulatory agencies required to put out regulations of a variety of types, and I think they are easily comparable in terms of their major overlap which is in the area of health-based regulations for chemical pollutants.

Both of these agencies have had a long and checkered career. Actually, their careers are of about the same length of time. They have both had ups and downs in a variety of ways. I think you can compare them pretty well.

There is a very big difference, though, in terms of where the regulatory science is done. In the case of EPA, the regulatory science is done within EPA. In the case of OSHA, it is done not in the Department of Labor, not within OSHA, but in Health and Human Services as part of CDC under NIOSH. So, it is a separate organizational component.

As well as being an environmental scientist, I am a physician. I am an occupational medicine physician. I run an occupational medicine program. My judgment is, and I think the judgment of just about everybody I have spoken to is that through the years, EPA has done a better job of getting out health-based regulations related to chemicals than has OSHA. I would think that, although we

can point to many factors, a major factor there is the presence of the health scientists within EPA as opposed to being in a separate organization.

And I want to immediately say that I have the utmost respect for the health scientists in NIOSH. I think they are excellent. I think they do a very good job of what they do. I think they have been very underfunded and perhaps can do more, but I think that not being, if you will, cheek by jowl with the regulatory has really hurt OSHA's ability to cut out health based regulations.

It is sort of ironic that one of the areas that NIOSH perhaps can be faulted with is the fact that they have not been able to develop a cadre of top-notch scientists around the country who are really knowledgeable about occupational health. It is a sister agency, it is NIESH, that has been able to do this for EPA.

So, there is a role for, if you will, basic science, more fundamental science, coming out of a nonregulatory agency. There is certainly a role for an organization such as the National Institute of Environment Health Sciences to provide the training grants and incentive programs which will allow the development of scientists—who will then be used in EPA science—who become either EPA scientists, or who become people in universities, or in other programs, who will be funded by EPA to provide the science necessary for the EPA regulatory efforts.

Besides that, there is the need to have research and development done within the regulatory agency. In terms again of the health-based science—and EPA obviously does more—but in terms of comparison with OSHA, it is easiest to compare the health regulations. There is within EPA a critical mass of scientists who are able to do two things.

One is the research and development itself. And the research and development, as Dr. Hendrie has said, that requires the kind of communication so that we can understand the questions that are to be asked. The question is the most important aspect.

At EPA, we have developed a process whereby the original planning is a joint planning between a research and development program and the program offices responsible for air or water or whatever particular program that focuses on what the question should be. It is a truism that scientists do a very poor job of explaining to the lay public what it is that they are doing. It is also a truism that nonscientists have a tough time explaining to the scientist what it is they need to have done.

This exchange is something that I think is really fostered by having your scientists within your regulatory agency. It simply will not occur if your scientists are in a completely different part of the Federal bureaucracy.

It is an exchange that goes on with course-corrections. You can talk about what the science is to regulators who are faced with the problem. They know that they have a year or two to develop the options, go through the various processes.

If, after talking with them, you sort of stay away from them during that period of time, you will find that there will be a gentle straying, not intentional, but a straying nevertheless from what the science base is, from what the technical base is. It is almost as if we started one of those games of whispers, just whisper into one

ear and go around. By the time it gets through a bunch of policy analysts, lawyers, and comes out the other end, it is subtly changed.

You need the continual interaction that occurs not just in the formal meetings that one can have between different agencies, but in the informal meetings, the corridor, picking up the phone, and meeting in the elevator that will keep the options fully based on the regulatory effort. Again, I think this is an argument to keep the research and development program within the regulatory agency to a large extent.

You can't just do it with health advisors or other scientific advisors who come in on a part-time basis or even are there full time if they don't manage any research programs. It is very, very tempting to say, "Why don't we hire a bunch of top-notch scientists and just let them always be at the Administrator's elbow and have them give advice?"

First of all, no one has the kind of breadth that is going to really provide all the advice necessary for an organization such as EPA or OSHA. Most of our regulatory agencies are reasonably broad in their need for different types of science.

Also, science is moving so rapidly that literally breathtaking advances are being made. In terms of health, if you have advisors who are not either performing or managing on-going research, they may be the best in the world right now, but in a few years, they are simply not going to be at the level of the scientists and technical people whom the regulated community have access to. You have to have people in your regulatory agencies who are at least as good as those in the regulated communities or you are going to find that the programs that you develop simply will not get through the courts, will simply not get through the expert review panels, the science advisory board, the National Academy of Sciences, that will be looking at what is done by the regulatory agencies.

I have also answered your questions in another way by listing for you a number of problems that I believe are inherent in a research and development program in a regulatory agency. There is a flip side to this. There are certain problems that simply don't happen in a Federal bureaucracy that is a research bureaucracy that do happen in the R&D program. I certainly had enough of them at EPA.

Most of them are manageable, not manageable in the sense that you are going to cure them, that some stroke of the pen, some congressional act will get rid of them, but manageable because you can recognize them and deal with them. Dr. Hendrie mentioned the different time frames that scientists and regulators act under. But these are manageable, not curable, but can be managed.

For instance, at EPA, I found one of my greatest frustrations would be to sit in with the Administrator or other people making decisions, watching them be very concerned about some major uncertainty in this process that they were working with and knowing that, damn it, if I had only known a year or two ago that this was the uncertainty that would be driving their decision, I couldn't have gotten rid of the uncertainty, but I certainly could have narrowed it down. I could have made it easier to make the appropriate decision had we known sufficiently far in advance.

Well, there are techniques and EPA in the past few years has certainly tried to develop a number of them, which will allow one to get the scientist and the regulator together, the technical person and the regulator together sufficiently early so that one can exchange the information which will anticipate what those decisionmaking processes will be dependent upon.

It is true that those decisionmaking processes at the time that the decision is made one can't say, "Gee, I have a great experiment which, if you give me about 2 years will help you," because Congress and the courts have set timetables that simply are not appropriate to wait that period of time.

Other problems that are inherent in the agency have to do with the lack of flexibility. We have a particularly bad one at EPA having to do with having inadequate resources for our in-house scientists. We are controlled, appropriately so, in the number of scientists that are present there. There are so many full-time equivalent people. There is so much of a budget. There are so many laboratories that must be maintained. I was told when I came to EPA that I could close a laboratory if I wanted to as long as I could find one that wasn't in a congressional district. So, we have very little option dealing with those types of numbers.

What we really have to do then is to be able to use the research and development budget we have for the people we have in-house and for the extramural program. Again, the controls are there to be sure that we don't build new buildings, we don't build palaces, we don't hire extra people, we don't spend money on acid deposition that Congress has decided should be spent on hazardous waste.

But beyond that, at EPA we were given an additional control. We heard earlier about the excellent work at the Jet Propulsion Laboratory. The research and development manager at NASA has the option to be able to use money, budgeted by Congress for certain work, at Jet Propulsion Laboratory or in-house at his own laboratories.

Basically, the kind of restrictions that EPA was under I did not have that type of flexibility. In fact, I had a severe shortage in the availability of funds to do in-house research. We had inefficiencies in-house because of a degree of micromanagement that came out of Congress, out of OMB, out of my own agency, and was based upon the failure to trust the regulatory agency which somehow was taken out upon the Research and Development Program, the scientists, which would not have happened at an agency that was not a regulatory agency.

So, again, unnecessary micromanagement based upon what the regulator has done which has gotten to some degree of displeasure of the various authorities responsible for the budget.

There are other inherent problems in doing the research in the agency. As I say, some of them can be cured. The last one I mentioned is curable, but most of them simply have to be looked at.

I will conclude by thanking you again for the opportunity and by telling you that I really believe, based upon my 2 years of experience, that we can work to get good health-based regulations at regulatory agencies, that we can manage to do a reasonably good job of separating the risk assessment and the risk management func-

tions, and that we can do a good job of controlling the tendencies in regulatory agencies toward misuse of science.

Thank you.

[The prepared statement of Dr. Goldstein follows:]

TESTIMONY

HEARING ON

SCIENCE IN THE MISSION AGENCIES AND FEDERAL LABORATORIES

COMMITTEE ON SCIENCE AND TECHNOLOGY

October 24, 1985

Bernard D. Goldstein, M.D.
Professor and Chairman
Department of Environmental and Community Medicine
UMDNJ-Rutgers Medical School
Busch Campus
Piscataway, NJ 08854

Mr. Chairman, Members of the Committee.

Thank you for inviting me to present my views on science in the regulatory agencies and federal laboratories. As you know, I have just returned to academia from the position of Assistant Administrator for Research and Development at EPA. Your probing questions in the Statement of Purpose for this hearing have led me to list the problems that exist in doing research in a regulatory agency. Before I describe them, and perhaps give the wrong overall impression, let me focus on your first question which asks whether R&D supporting regulatory offices should be under the control of the regulatory agency, or elsewhere in the bureaucracy; presumably a science based organization.

As an academic scientist, I am much more comfortable dealing with experimental evidence rather than with opinions. Fortunately for me, the Federal Government has conducted an experiment which provides information pertinent to the question of where regulatory science and technology should be performed. This is the experiment in which R&D has been included within EPA but excluded from OSHA. OSHA, which is part of the Department of Labor, has its regulatory mission supported by NIOSH, which is associated with the Center for Disease Control and is part of the Department of Health and Human Services. The greatest overlap in the missions of EPA and OSHA is in the area of health based standards for the control of exposure to chemicals. Therefore one can get some insight into which of the two approaches is most effective by comparing the ability of OSHA and EPA to produce health-based regulation of chemicals. Both organizations were begun more than a decade ago, both have experienced periods of strong and weak leadership; ups and downs in funding; and a reasonably similar checkered career in terms of employee morale and other factors pertinent to effective regulation action. In my judgment, and

the judgment of everyone I've spoken to on this matter, EPA clearly has done a better job in producing health-based regulation of chemicals. I give this judgment not only as a scientist who has spent two years at EPA but as a physician in charge of an occupational health program.

I believe that including R&D within the structure of EPA has been an important part of EPA's relative success in this area, although there are many other factors that have played a role. Let me immediately state that I am not arguing that EPA has better health scientists who have done more effective research than NIOSH supported scientists. I have the upmost respect for the capabilities of NIOSH, although it has been grossly underfunded. NIOSH can be faulted for not having done a fraction of what needs to be done to ensure that there are highly qualified occupational health scientists in the nation's academic programs providing the R&D necessary for NIOSH activities. It is somewhat ironic that it has been a sister NHS organization, NIEHS, that has been responsible through the judicious use of training programs and center grants for a major part of the availability of top notch scientists to work in or with EPA, and provide it with the scientific base leading to effective regulation.

The presence of an R&D program within EPA has led to a critical mass of health scientists who participate not only in the development of pertinent scientific data but, most importantly, in the translation of the world's literature into the basis for regulatory decision-making. Of significance is that at EPA this is done by a separate line organization headed by an Assistant Administrator, a political appointee. This helps maintain organizational recognition of a legitimate role for R&D as part of the Agency's mission, and provides the opportunity for the individual responsible for health science to give the information on which regulation is based to the highest levels of the Agency. This exchange of information, and the

important course corrections that are needed as non-scientists stray from the acceptable data base, occurs not only through formal meetings and position papers, but to a large extent through multiple informal exchanges in offices, elevators, corridors and the other interactions that characterize any effective organization. Note that this is a 2-way exchange. It is a truism that scientists do a poor job in translating what they know to the non-scientist. I can attest it is also a truism that non-scientists have great difficulty in describing to scientists what it is they need to know to be able to make a regulatory decision. At EPA we set up a formal process for research planning in which the questions to be asked were determined jointly by the Office of Research and Development and the appropriate program office. Of importance, ORD's success in obtaining support within the Agency is dependent on the success of this interaction, in essence on the ability to provide information which is necessary for regulation. Such a close and effective association can not be obtained when the health science activity is performed in a separate federal bureaucracy. Nor can this be accomplished simply by having well-qualified health scientists serve in advisory roles. First of all, the communication required is not just at the senior levels of the agency, but throughout. In fact, in terms of timely regulation, it is crucial that junior and mid-level policy analysts and lawyers have the benefit of communication with health scientists: failing this an otherwise well worked out regulatory package will be turned down on scientific grounds at a high agency level only after many months of work at lower levels, or a research approach that could have provided information needed to narrow uncertainty will be recoganized much too late in the regulatory process to be of timely value. Another problem with an approach primarily depending upon using scientific advisors is that it fails to recognize the essential feature

of modern health science - its rapid progress. Breathtaking advances are being made every day. Health advisors who are not performing or managing active research programs simply can not be expected to provide information over the long term that will successfully pass review by a a Science Advisory Board, or stand up in court. Regulatory agencies must have scientists who are at least as qualified as those available to the regulated community.

Let me now turn to the problems of R&D in a regulatory agency, and in this discussion I refer to all of R&D and not just to the health studies used as an example for the comparison of OSHA and EPA. The problems are many. The one of greatest concern is the possibility that risk assessment and risk management will not be kept separate, that the scientist will only provide those answers convenient to the regulator. I will not tell you that has not happened at EPA in the past, nor that it can not happen in the future. However, the current approach which relies heavily on external peer review through the Science Advisory Board and other mechanisms should make recurrences much less likely. The scientific community has a vested interest in seeing that EPA's risk managers are restricted to participating in determining the questions to be asked, not the answers that are given.

There are other problems that are specific to performing research in a regulatory agency. A major one is the frequency in which well-planned pertinent ongoing research must suddenly be stopped. This is highly inefficient, more so than the stops and starts so frequent in the regulatory world, in that the restarting process is exceptionally costly for the type of research that is done by EPA. Suddenly stopping an EPA reseach project often wipes out the whole investment. Sometimes this is justified. As public servants it is appropriate for EPA scientists to respond to sudden public needs, often expressed through Congress, such as Love Canal, dioxin, etc. In fact, it is the need to respond quickly which is a partial justification for

having scientists directly responsive to an Administrator who can make the judgment that the provision of information on a new topic justifies the sacrifice of an existing programmatic need. This is difficult to do if the scientists who will be impacted by the change work in a completely different part of the bueaucracy. The wise R&D manager has bufffering systems in place to allow some flexiblity in switching R&D objectives. However, in my experience, only rarely is the need to stop ongoing research, with its associated waste of taxpayers' money and adverse impact on scientists' morale, justified by new work to be done. The major cause of this problem, at least at EPA, is a budgeting process that simply is not congruent with the realities of the efficient performance of R&D. Unfortunately, I believe there is a tendency for this to be inherent in a regulatory agency, although much improvement can be made. There are two major causes, one within the agency and a second in which Congress and OMB can be added to the list of culprits. Within the agency there is what I call the "green eyeshade syndrome". A well-documented positive aspect of modern bureaucracies is the frequency with which technocrats, such as accountants, become firmly imbued with the mission of the agency. In a federal research bureaucracy the mission is research; at a regulatory agency it is regulation. It is no wonder that EPA's budgetary staff has treated the agency's R&D budget as a piggybank often producing highly negative and wasteful long term effects on the R&D needed to support regulatory decision-making in exchange for transitory immediate gains for a floundering regulatory program. The second budgetary problem leading to inefficiency and morale problems that tends to be particular to a regulatory R&D program is the unwarranted degree of control exercised by individuals in EPA, at OMB and in Congress who simply do not understand the first thing about managing an R&D program. Note that I am not objecting to control in principal

by all levels, it is the degree of control. Certainly it would be wasteful to ask EPA accountants, or Congress or OMB to choose the strain of rat for an experiment. While it has not gone that far it is in that direction that controls have hamstrung EPA's R&D efforts. One important example is the restrictions placed on EPA's in-house research program which greatly jeopardizes the productivity of 1800 dedicated federal employees. Unique among all federal R&D organization, including other regulatory agencies, EPA is restricted in using its research budget for in-house projects. This would not be as major a problem if the approach to the budget by Congress and the executive were appropriate. In fact, actions by Congress and OMB tend to make a mockery of the very careful R&D planning undertaken within the agency. Last minute changes in total budgets and particularly in subdivisions of the budget, are made for reasons extraneous to the research planning. That of course happens to some extent at every federal agency, but at EPA it is uniquely difficult to manage because of the additional micromanagement by individuals incompetent to manage an R&D program. The net result has been to greatly impede the ability of EPA's in-house R&D program to effectively perform research planned and budgeted completely in agreement with the dictates of the Administration and of Congress. Please note that I am not talking about more money, nor am I talking about relaxing controls on the number of employees or the use of funds to build or renovate laboratories; what I am attempting to describe is a situation in which the manager of R&D at EPA has lost the flexibility to decide whether planned research should be performed at EPA laboratories or extramural laboratories, and is forced into making unreasonable and counterproductive demands on EPA laboratory scientists. This problem began in the Carter Administration and accelerated in the Reagan Administration. It is unique to a regulatory agency in that it reflects actions taken because of a dissatisfaction and distrust with the

regulator. It can and should be reversed.

There are other problems in doing research in a regulatory agency that are not reversible in the sense that there is no law of Congress or management approach that will provide a final solution. Rather, these are problems inherent to regulatory agency research.

An example of an inherent problem is the difficulty in obtaining validation of models and other tests used in regulatory efforts. EPA is justly proud of its ability to produce models for the calculation of exposure, or batteries of tests to predict chemical toxicity. However, as has recently been pointed out by the Science Advisory Board, EPA should be doing a better job of validating, or field testing, to test the accuracy of predictive models or tests. The reason for this is related to the interface between regulation and research. Scientists are relatively conserative in the use of data. If left to ourselves, we might go to 18 decimal places before we will accept a fact. On the other hand, regulators do not have the time to wait for 18 decimal places. This leads within the agency to budgeting decisions each year which favor developing a new model or test battery for another problem rather than validating the existing one. A somewhat related inherent problem of doing research in a regulatory agency is the different time frames of scientists and regulators. The time frame of the regulatory process, very ofren conditioned by Congress, puts pressure on scientists to do or accept less than optimal R&D in order to satisfy a short-term need. An R&D manager must be alert to insure that the quality threshold is always exceeded. This can be done by careful attention to quality assurance and quality control (QA/QC). But again, it is difficult to convince regulators of the need for QA/QC due to their greater willingness to accept any number they can get.

Other problems inherent in doing R&D in a regulatory agency relate to the

planning process. In deciding which investigators to support, scientists tend to focus on past track records while regulators look more at what is said will be done, as in an essay contest. The uncertainties of research outcome tend to hamper wise investment in relatively high risk research which might be extremely beneficial to the regulatory mission, but whose outcome is not fully predictable...

Having listed some of the problems inherent in doing research in a regulatory agency, let me immediately emphasize that all of these problems are manageable. By manageable I don't mean in the sense of a final cure. However, if one recognizes these problems, and works at them, they can be ameliorated.

A question frequently asked is whether EPA's research effort unnecessarily duplicates that supported by other federal agencies. The answer is no. Let me discuss health research since this represents the greatest likelihood for overlap, given the strength of federally supported environmental health research. My judgment in this area is based in part on my past experience as Chairman of the NIH Toxicology Study Section, which reviews and assigns priority for the funding of research grants in Toxicology, and also as the recipient of three NIH grants. The distinction between EPA supported and NIH supported health science research is subtle, but it is real and of great importance to providing the type of research findings necessary for effective regulation. In essence, NIH supported research provides the basic science on which regulatory health science is based. A high quality proposal aimed at establishing the underlying mechanism by which a pollutant produces an adverse effect will be funded by NIH; a proposal of a similar quality aimed at utilizing this mechanistic insight to establish the lowest observed effect level or other numerical risk data of value to the regulator would almost certainly not receive sufficient priority from an NIH Study

Section to be funded. Let me emphasize that the regulator could not ask questions related to risk if the mechanistic insight had not first been provided by NIH funded research. Accordingly, both are needed: the free-floating high risk basic science approach in which the role of the government is to assign priorities over relatively broad areas and to ensure that there are sufficient experts trained in our universities and sufficient tools for these experts to provide the basic foundation without which advances will not occur, and the more directed research aimed at answering specific questions of importance to the regulator in which close interaction between regulators and scientists is a necessity so as to define the question in a form that will provide an answer. Central to all research is the need to define the problem in terms of crucial experiment. To the academic scientist a crucial experiment is one that tells us something we didn't know before, or to be trite, one that advances the frontiers of science. To the regulatory scientist the definition of crucial is related to the mission of the agency, but otherwise the same need is there. Note that this is not equivalent to a distinction between long-term and short-term, or basic and applied. Certain long-term basic questions can be identified as crucial to the needs of a regulatory mission and should be funded (e.g. better understanding of the mechanism by which different soils interact with groundwater contaminants).

Let me also point out that one must distinguish between overlap in the managing of R&D, which produces wasteful duplication and confused signals, and overlap in the performance of R&D, which is the normal way that science and technology progress. Contrary to the public image, isolated scientific and technical breakthroughs are exceptionally rare. Advances in knowledge require replication, preferably by different scientists using varying approaches, before they will be accepted. A good R&D manager acts to allow some

redundancy in research efforts, particularly on the margin between scientific areas. This is more preferable to rigid lines of demarcation which allow needed research to fall in the gap.

Your question concerning whether research of value to the mission of a regulatory agency is best done in the regulatory agency, or in a separate scientific organization, is particularly timely. There is now under consideration the funding of research and development under the Superfund bill, something that is desperately needed, and the appropriate venue for such funding. There appears to be a sentiment in Congress toward giving major control of the R&D funding to the Agency for Toxic Substances and Disease Registry (ATSDR). This would be a mistake for at least four reasons. First of all, it flies in the face of the "experimental" results which show EPA having a better track record than OSHA in using health science. In this regard, it should be noted that ATSDR occupies approximately the same position as NIOSH in the HHS table of organization. Secondly, for most of the R&D areas needed for Superfund decision making, ATSDR does not have the scientific or technical strength. Given the immediate needs of Superfund, it appears inappropriate to build new areas into ATSDR which duplicate existing strengths at NIEHS, EPA and the nation's universities. As part of CDC, ATSDR does have major important strengths in epidemiology and should be strongly supported to perform the necessary hands-on disease registry studies at Superfund sites, and related research.

Thirdly, for this important program requiring rapid response, the power to demand this flexibility is removed from the head of EPA who bears the responsibility for decisions made on the basis of the R&D products. Accountability without authority is a prescription for failure. Fourthly, there is a very strong potential for managerial overlap leading to confusion. In the not unlikely event that ATSDR will provide a somewhat different

interpretation of the risk of a toxic substance than does EPA's R&D program, to whom does the Administrator of EPA listen? There is little sense in building ATSDR up to have expertise in a broad area, particularly risk assessment, unless Congress intends for the Administrator of EPA to use its advice. But, by the same token, the advice given by EPA's R&D program, which has a leadership role in risk assessment and which relies heavily on outside scientific peer review, will presumably still be relied upon for the other dozen or so Acts which are under the responsibility of the EPA Administrator. To have the head of EPA use one inherent risk number or finding for a compound when it is regulated under Superfund, and another number when it is regulated under the Clean Air Act, is a prescription for administrative paralysis which, at a minimum, will further slow up a process that Congress has frequently criticized for its slowness.

In summary, I would answer your question by saying that it does matter where in the bureauracy regulation-related research lies. Mission oriented agencies can best accomplish their mission if they maintain R&D programs. As I have discussed, there are certain problems that are inherent in performing R&D in a regulatory agency. But these can be dealt with, and such problems are far outweighed by the benefits of performing R&D in a situation where one optimizes the ability to ask the right questions, and where the scientist and engineer can be most responsive to the needs of the mission.

Mr. WALGREN. Thank you, Dr. Goldstein.
Mr. Jorling?

STATEMENT OF THOMAS C. JORLING, PROFESSOR OF ENVIRONMENTAL STUDIES, WILLIAMS COLLEGE, WILLIAMS TOWN, MA; AND FORMER ASSISTANT ADMINISTRATOR FOR WATER AND HAZARDOUS MATERIALS, U.S. ENVIRONMENTAL PROTECTION AGENCY

Mr. JORLING. Thank you, Mr. Chairman. I, too, am pleased to be here and honored to speak to these issues. I do commend you and the staff for the work that you have performed, not just with the issue that we are speaking to but the overall question of science policy in the Federal Government.

Unlike my two colleagues, I come to this task as one who speaks as an environmental regulator and not as an environmental scientist. I spent time leading a regulatory arm of EPA, not the research arm. I, too, will direct my responses to the questions you specifically raised in your letter of invitation.

On the first question, I share the affirmative answer that both of the preceding witnesses have given. I would add some emphasis to it. I would say that not only is the answer yes that a regulatory agency must have an in-house R&D program, but that it is decisively and emphatically yes.

The regulatory agencies should maintain R&D programs within their organizations. The R&D necessary to support regulation should not, and I would add even stronger, cannot be conducted in another agency or agencies. It does make a difference where and by whom regulation related research is performed.

EPA is an example of a regulatory agency charged by Congress in a series of major enactments with a most important but difficult task, simply put, to protect public health and to enhance and maintain the integrity and quality of the environment. It is a difficult task because it involves all of the following: science and technology; economic factors; health and welfare; volatile political dynamics, uncertainty, and emotion. And lest anyone misinterpret the inclusion of this latter point, I strongly value the emotional element in these processes.

Above all, environmental regulation involves large numbers of very diverse people and institutions, all having very different views and interests on any typical environmental issue. It involves the States and, often, local government. It involves public and private officials. It impacts nearly every sector of our society. Thus, environmental regulation is and it must be a competitive process. It is a competitive political process, competitive in the sense that all parties work very hard, and some employ huge banks of resources, to represent their interests at every step of the process.

In the context of science, what comes before the agency is advocacy science. No one should be under any illusion that the science that is injected into rulemaking and decisionmaking is calm, dispassionate, objective, neutral, and rational. It is not. Science, or the mantle of science, is advanced to make a point. Not once in my experience has a representative of the regulated sector come forward and said, "Our scientific research reveals we have a problem on

which we need tighter regulation." Establishing that fact is a burden on Government, on the public, or on the environment. It is in this sense that science introduced into the regulatory process is advocacy science.

I believe this competitive process is important to the success of democracy. It involves wide participation; although great disparities in access to resources can distort that participation, especially in the area of science and technical issues. It avoids tyranny of the "expert". It avoids making big errors. It might be slow and it might be messy, but it represents better government than any alternative that has been proposed.

Essential to the ability of EPA to serve in a decisionmaking capacity in such processes is the availability of a competent scientific research and technical arm. Simply put, EPA—and I believe any agency regulating in the area of health and the environment—must have scientific and technical resources that are operating not only under the same mandate from Congress but also within the same organization that is responsible for the ultimate regulatory performance. Just as the regulating arms of the executive branch need congressional authorization and direction and also need to be accountable to Congress and the courts, so too does the scientific and technical arm. Science in these areas needs to be responsive to public policy; responsive in what it pursues, when it pursues it, and how it pursues it. In short, it is necessary to support the regulatory process.

To the objection that science can't be directed or accelerated or operated in any hurried or hassled environment, I say nonsense. Often, such an objection, made in the tone of utmost reasonableness, is, simply put, B'rer Rabbit asking not to be thrown in the briar patch. Any knowledgeable observer or participant knows a very effective way to hobble a regulatory agency is to remove its control over the scientific and technical personnel or otherwise reduce its capacity to perform such work. That is, seeking to deprive EPA of its scientific resources is a tactic in an effort to seek a desired outcome, usually, an outcome in the form of delayed or avoided regulation.

In areas of public policy, science can be directed, even hurried. The Manhattan project and the man on the Moon are loud testaments to that fact. In the context of EPA regulation—and I share Dr. Goldstein's views on this—scientific and technical work has supported work having the effect of protecting health and environment long before actions would have been taken if EPA was dependent upon so-called neutral, if not neutered, source of science and technical assistance.

I am speaking here to the issue of whether EPA should have a research arm, not to issues which relate to the question of whether EPA science can't be made better or more integrated into decisionmaking. Your first question is of a much larger scope than leadership and management in the agency. If we have time, I will address those later.

Let me recite real world experience in support of a regulatory agency having its own scientific and technical resources. The results of EPA decisionmaking, generally rules, are nearly always subject to judicial review. The courts are asked, in effect, to judge

the defensibility of actions taken by the agency. Often, those rules have a strong scientific and technical component or basis, and that component or basis is nearly always attacked by the challenging parties.

EPA has several sources for its scientific and technical needs. Sometimes, because of the exigency of a situation, it must depend on whichever of these sources is available. Sources of scientific information include the regulated community itself, the States, the literature, grantees, consultants, and contractors, and, of course, EPA's own staff.

It is appropriate to ask, then, which source of science and technical support is the most dependable, dependable in the sense that it withstands the scrutiny of the courtroom. That answer, according to every attorney I have interacted with at EPA and in the Department of Justice and in every case that I am familiar with, is EPA's own scientific and technical staff. In fact, repeatedly, as part of rulemaking activities, I have had EPA lawyers advise me repeatedly that regulations were not defensible unless they were supported by EPA work.

Remember what is involved here. For one, a willingness to stand behind, in public, often on the witness stand, the science and the judgments and conclusions drawn from it. Suffice it to say that neutral scientists do not like to be cross examined.

Second, science in the regulatory process involves an exact level of quality control. People who are not on the anvil of the legal process are notoriously sloppy. The standards of quality control demanded of science and technical questions in public policy are much greater than in the scientific methods otherwise operating in academia. It is more demanding because real consequences, often investment of substantial resources, flow from the actions of EPA. Only persons in such an institution and held accountable to such standards are typically ready to withstand that kind of scrutiny.

So-called independent consultants or contractors, and here I am sorry to say I would for the most part include the National Academy of Sciences, are never independent of the sources and potential sources of funds or of the bias of the personnel who comprise such organizations. Repeatedly, in my experience, EPA contracts for scientific and technical support were made with firms or organizations that also perform similar services for the regulated sector. Such contractors are not and cannot be unmindful of the effect of their results under such contracts on present or future clients.

Enough said except for one related point, and this again bears on one of Dr. Goldstein's points. It is important to ask why EPA depends on contractors at all. The most important reason is a budget principle, a budget principle common to all administrations, that makes it easier for an agency to get contract money than to obtain authorization internal or civil service personnel. The principle is supported by an assumption that I believe to be fundamentally flawed, that it is cheaper in the long run to hire a consultant, even at a much higher rate of cost and with lower performance, than a civil servant. The existence of the "Beltway Bandits" is testimony to the beneficiaries of this budget assumption. The beneficiary of this principle certainly isn't the public interest or the taxpayer.

Your second question deals with maintaining quality science in the face of regulatory deadlines.

In general, there is no obvious structural solution to the problem implicit in this question. Assuring quality, and I would add relevant science, in the rulemaking process depends a great deal on leadership and management, in short, on good people. As a result of my experience, I can suggest several themes that bear on these questions but I recognize fully that in the end they may be no more than mere exhortations.

The regulators, budgeters, and planners in the agency must respect the needs, the personnel needs, the equipment needs, the budget need, and the procedural needs of R&D. This means sufficient resources must be assured for R&D. The first cuts in times of austerity, a perpetual condition now, can't simply be taken from R&D. The level of commitment must be sustained over the long haul. Simply put, the pattern of the last 5 years or so which resulted in a 50-percent reduction in EPA R&D resources at the same time the agency was faced with major new responsibilities cannot be allowed to be repeated.

Second, R&D personnel, especially R&D leaders, must interact with regulatory personnel. Regulations and public policy decisions are much more effective if both the regulator and the R&D arms are marching to the same drummer—a drummer which, in the final analysis is Congress sounding through its statutory authorizations and in its oversight responsibility.

I am a firm believer in deadlines, a believer even long before they were demonstrated to work. Normally, in health and environmental protection, there is never a time when the science is complete. Consequently, it becomes a question of judgment, scientific and regulatory judgment, when there is enough information to act and, with good leadership, R&D can supply that amount of science and technical information plus assist in making appropriate judgments about it on a timely basis. I think it is a strawman, if not a diversion, to point to incomplete science as an attack on regulatory deadlines. Science is never complete. The issue is when and whether prudent judgments, informed by science, can be made.

I have combined your last two questions for the purposes of my final comments. I do so because I think, in effect, they represent the front and the back end of the same issue, specifically, the issue of how regulatory and scientific personnel communicate. This is another issue for which structural solutions are secondary to good people, and I can again only make suggestions. R&D personnel should be involved on the work groups, task forces, or whatever is called the committee responsible for moving the regulation or public policy decision forward. I think, at least in form, this is standard practice, but to make it work, the R&D personnel must have access to resources so that as questions arise with scientific and technical dimension, those questions can be addressed on a timely basis.

I am concerned that the text of these two questions suggests a degree of disjunction between science and regulation which I do not believe exists. The science/nonscience division is not a clear one in public policy issues involving health and the environment. There are no discrete parts of any issue which can be split off into the

domain of science and treated differently and then simply plugged into decision formulas. All elements of a complicated policy issue need good science, good analysis, good process, and ultimately reasoned judgment. This can only be accomplished by teams working together with the people responsible for the different elements of an issue, the science, the economic analysis, the policy analysis, all contributing their respective knowledge in the overall process of developing a regulation or making a decision. What the scientist needs to participate effectively in such process is stable, adequate resources and staff in laboratories or in the field and the lead time to perform the work.

My point is that neither science nor the scientist is or can be immune from the give and take of the rulemaking or public decisionmaking process. The scientific issues are woven too deeply into policy issues.

I would like to summarize to this point. I believe it is absolutely essential for agencies such as EPA that regulate in difficult and complicated technical areas to have R&D capacity. That capacity should be meaningful, that is, properly staffed, equipped, and funded. Moreover, scientific and technical personnel must be integrated into every stage of the rulemaking or decisionmaking process. Only in such a manner can the scientific and technical component of issues be incorporated soundly into public policy. These are highly competitive processes, and the agency must have skilled professionals, scientists and nonscientists alike, operating together to carry out the mandate of Congress.

This is not to say that everything is fine in EPA relative to science. It isn't. But on the macroscale question, I am saying that EPA must have a research arm, and it must be given adequate staff, equipment, and funds. It must also be fully involved in the decisionmaking process of the agency.

These elements are essential. Given them, the agency can perform, perhaps not always well, but perform through periods of upheaval or turmoil at the top such as we have recently witnessed, and through periods when events and issues emerge which dominate the political and public perception.

Thank you, Mr. Chairman. I would be happy to answer any questions.

[The prepared statement of Mr. Jorling follows:]

TESTIMONY

THOMAS C. JORLING
WILLIAMS COLLEGE, WILLIAMSTOWN, MA.
BEFORE THE TASK FORCE ON SCIENCE POLICY
OF THE U.S. HOUSE OF REPRESENTATIVES COMMITTEE
ON SCIENCE AND TECHNOLOGY

Mr. Chairman and Members of the Task Force, I am honored by your invitation to appear before you on issues of Science and the Mission Agencies and Federal Laboratories. My comments to you are informed by three principal experiences. First service on the staff of the U.S. Senate Committee on Environment and Public Works during the period 1968-72; a period which included the birth of EPA and the enactment of several of its principal authorizing statutes. Second, service as Assistant Administrator of EPA for Water and Hazardous Materials during the period 1977-79; with responsibilities for implementing four major regulatory statutes; the clean Water Act, the Ocean Dumping Act, the Safe Drinking Water Act and the Resource Conservation and Recovery Act and third, service as a student and teacher of environmental protection as a Professor of Environmental Studies at Williams College from 1973-77 and from 1980 to the present. In the context of this hearing, my remarks will focus on the role of science in environmental regulation, primarily as that regulation is carried out by the U.S.E.P.A. My views are those of an environmental regulator, not those of a scientist. They are the views of one who has lead a regulating arm of EPA, not a research arm.

You and your staff are to be commended for the preparatory work on these hearings and the overall study of Science Policy. I am going to take the specific questions in your letter of invitation as a starting point for my comments.

Question 1.

> "Should regulatory agencies maintain R&D programs, or should their be conducted by another agency or agencies? In other words, does it matter where in the bureaucracy regulation-related research lies?"

The answer is most decisively and emphatically yes. The regulatory agencies should maintain R&D programs within their organizations. The R&D necessary to

support regulation should not, even stronger, cannot be - conducted in another agency or agencies. It does make a differnece where and by whom regulation-related research is performed.

EPA is an example of a regulatory agency, charged by Congress in a series of major enactments with most important, but difficult tasks: simply put, to protect public health and to enhance and maintain the integrity and quality of the environment. It is a difficult task because it involves all of the following: science and technology; economic factors; health and welfare; volatile political dynamics, uncertainty, and emotion. And lest anyone misinterpret the inclusior of this latter point - I strongly value the emotional element in these processes.

Above all, environmental regulation involves large numbers of very diverse people and institutions; all having very different views and interests on any typical environmental issue. It involves the states and often local government; it involves public and private officials. It impacts nearly every sector of our society. Environmental regulation is a competitive process, competitive in the sense that all parties work very hared, and some deploy hugh banks of resources, to represent their interests at every step in the process.

In the context of science - what comes before the Agency is advocacy science. No one should be under any illusion that the science that is injected into rulemaking and decisionmaking is calm, dispassionate, objective, neutral and rational. It is not; science or the mantle of science is advanced to make a point. Not once in my experience has a representative of the regulated sector come forward and said our science research reveals we have a problem on which we need tighter regulation. Establishing that fact is a burden on government, or the public, or the environment. It is in this sense that science introduced into the regulatory processes advocacy science.

I believe this competitive process is important to the success of a

Democracy. It involves wide participation; although great disparities in access to resources can distort that participation, especially in the area of science and technical issues. It avoids tyranny of the "expert". It avoids making big errors. It might be slow, it might be messy, but it represents better government than any alternative that has been proposed.

Essential to the ability of EPA to serve in a decision making capacity in such processes is the availability of a competent scientific research and technical arm.

Simply put EPA - and I believe any agency regulating in the area of health and the environment - must have scientific and technical resources that are operating not only under the same mandate from Congress, but also within the same organization that is responsible for performance. Just as the regulating arms of the Executive Branch need Congressional authorization and direction, and also need to be accountable to Congress and the Courts, so to does the scientific and technical arm. Science in these areas needs to be responsive to public policy; responsive in what it pursues, when it pursues it, and how it pursues it. In short, it is necessary to support the regulatory process.

To the objection that science can't be directed or accelerated or operate in any hurried or hasseled environment, I say nonsense. Often such an objection - made in the tone of utmost reasonableness - is, simply put, B'rer Rabbit pleading not be to thrown in the Briar Patch. Any knowledgeable observer or participant knows a very effective way to hobble a regulatory agency is to remove its control over it scientific and technical personnel. That is seeking to deprive EPA of its scientific resources is a tactic in an effort to seek a desired outcome - usually an outcome in the form of delayed or avoided regulation. In areas of public policy, science can be directed, even hurried. The Manhattan Project and the Man on the Moon are loud testament to that fact. In the context of EPA regulation, science

and technical work has supported action having the effect of protecting health or the environment long before actions would have been taken if EPA was dependent on a so called independent neutral, if not neuter, source of science and technical assistance.

I am speaking here to the issue of whether EPA should have a research arm - not to issues related to making EPA's science better or more integrated into decision making. Your first question is of a much larger scope than leadership and mangement in the Agency. If we have time I will address those issues later.

Let me recite real world experience in support of a regulatory agency having its own scientific and technical resources. The results of EPA decision making - genrally rules - are nearly always subject to judicial review. The courts are asked in effect to judge the defensibility of actions taken by the agency. Often those rules have a strong scientific or technical component or basis and that component or basis is nearly always attacked by the challenging parties.

EPA has several sources for its scientific and technical needs. Sometimes because of the exigency of a situation, it must depend on whichever of these sources is available. Sources of scientific information include the regulated community, the States, "the literature," consultants and contractors, and, of course, EPA's own staff. It is appropriate to ask - which source of science and technical support is the most dependable; most dependable in the sense that it withstands the scrutiny of the courtroom. The answer according to every attorney I interacted with at EPA and the Department of Justice was EPA's own scientific and technical staff. In fact, I had EPA lawyers advise me repeatedly that regulations weren't defensible unless they were supported by EPA work. Remember what is involved here. For one, willingness to stand behind - in public, often on the witness stand - the science and the judgements and conclusions drawn from it. Suffice it to say, "neutral"

scientists do not like to be cross-examined. Second, science in the regulatory process involves an exact level of quality control; people who are not on the anvil of the legal process are notoriously sloppy. The standards of quality control demanded of science and technical questions in public policy are much greater than in the scientific methods otherwise operating in academia. It is more demanding because real consequences, often the investment of substantial resources, flow from the actions of EPA. Only persons in such an institution are typically ready to withstand that kind of scrutiny. So called independent consultants or contractors - and here I am sorry to say I would for the most part include the National Academy of Sciences - are never independent of sources or potential sources of funds or of the bias of the personnel who comprise such organizations. Repeatedly in my expereince EPA's contracts for scientific or technical support were made with firms or organizations that also performed 'similar' services for the regulated sector. Such contractors are not - and cannot be - unmindful of the effect of their results under such contracts on present or future clients. Enough said, except for one related point.

It is important to ask why EPA depends on contractors at all. The most important reason is a budget principle - common to all administrations - that make it easier for an agency to get contract money than to obtain authorization to hire civil servants. The principle is supported by an assumption, that I believe to be fundamentally flawed, that its chepaer in the long run to hire a consultant - even at a much higher rate of costs and with lower performance - than a civil servant. The existence of Beltway Bandits is testimony to the beneficiaries of this budget assumption. The beneficiary of this principle certainly isn't the public interest or the taxpayer.

Question 2.

> "How should regulatory agencies maintain quality science in the face of regularoy deadlines?"

In general there is no obvious structural solution to the problem implicit

in this question. Assuring quality, and I would add, relevant science in the rule-making process depends a great deal on leadership and management - in short on good people. As a result of my experience I can suggest several themes that bear on these questions, but I recognize fully that, in the end, they may be no more than exhortations.

The regulators, budgeters, and planners in the agency must respect the needs; personnel needs, equipment needs, budget needs and procedural needs of R&D. This means sufficient resources must be assured for R&D. The first cuts in times of austerity - a perpetual condition now - can't be simply taken from R&D. The level of commitment must be sustained over the long haul.

Second. R&D personnel, especially R&&D leaders, must interact with regulatory personnel. Regulations and public policy decisions are much more effective if both the regulator and the R&D arms are marching to the same drummer, a drummer which in the final analysis is Congress, sounding through its statutory authorizations and in its oversight responsibility.

I am a firm believer in deadlines - a believer even before they were demonstrated to work. Normally, in health and environmental protection there is never a time when the science is "complete." Consequently, it becomes a question of judgement, scientific and regulatory judement, when there is enough information to act and, with good leadership R&D can supply that amount of science and technical information, plus assist in making appropriate judgements about it on a timely basis. I think it is a straw man, if not a diversion, to point to "incomplete science" as an attack on regulatory deadlines. Science is never complete. The issue is when and whether prudent judgements informed by science can be made.

Question 3.

> "How should a regulatory agency translate regulatory questions framed by non-scientists into scientific questions that research can address?"

Question 4.

> "How are scientific research results best translated into the

regulatory arms of the agency?"

I have combined these two questions because, in effect, they represent the front and backend of the same issue: how do regulatory and scientific and technical personnel communicate. This is another issue for which structural solutions are secondary to good people and again I can only make suggestions. R&D personnel should be involved on the work groups, Task Forces, or whatever is called the Committee responsible for moving a regulation or public policy decision forward. I think, at least in form, this is standard practice, but to make it work, the R&D personnel must have access to resources so that as questions arise with a scientific or technical dimension, those questions can be addressed on a timely basis.

I am concerned that the text of these two questions suggests a degree of disjunction between science and regulation which I do not believe exists. The science - non-science division is not a clear one in public policy issues involving health and the environment. There are no discrete parts of any issue which can split off into the domain of science and treated differently and then simply plugged into decision formulas. All elements of a complicated policy issue need good science, good analysis, good process and ultimately reasoned judgement. This can only be accomplished by teams working together with the people responsible for the different elements of an issue - the science, the economic analysis, the policy analysis - all contributing their respective knowledge in the overall process of developing a regulation or making a decision. What the scientist needs to participate effectively in such process is stable, adequate resources and staff in laboratories or in the field, and the lead time to perform the work.

My point is that neither science nor the scientist is, nor can be immune from the give and take of the rule-making or public decision making process. The scientific issues are woven too deeply into the policy issues.

I would like to summarize to this point. I believe it is absolutely essential for agencies such as EPA that regulate in difficult and complicated technical areas to have R&D capacity. That capacity should be meaningful; that is properly staffed, equipped and funded. Moreover, scientific and technical personnel must be integrated into every stage of the rule making or decision making process. Only in such manner can the scientific and technical component of issues be incorporated soundly into public policy. These are highly competitive processes and the Agency must have skilled professionals, scientist and non-scientist alike, operating together to carry out the mandate of Congress.

This is not to say everything is fine in EPA relative to science. It isn't. But on the macro-scale question, I am saying EPA must have a research arm, and it must be given adequate staff, equipment and funds. It must also be fully involved in the decision making processes of the Agency. These elements are essential; given them the Agency can perform - perhaps not always well - but perform through periods of upheaval or turmoil at the top, such as we have recently witnessed; and through periods when events or issues emerge which dominate the political and public perceptions.

Mr. WALGREN. Thank you, Mr. Jorling.

I hear Dr. Hendrie saying that there has to be a pretty complete separation, and then I hear both of the succeeding gentlemen saying there has to be pretty close contact. Can these views be reconciled? Have you, Dr. Hendrie, been sitting there saying, "Gee, I disagree with what these folks are saying"? Or did you folks, in listening to Dr. Hendrie, say you were in disagreement with him?

Dr. HENDRIE. In establishing research projects, you can certainly and must establish projected schedules. Research people, like other people, can attempt to make schedules.

My own view is that the difference you sense here on the panel derives in good part from the differences in the way in which our mother agencies conduct their affairs. EPA has always had in-house laboratories. I come from the Atomic Energy Commission, Department of Energy, Nuclear Regulatory Commission side of the Government where we have never had in-house laboratories and have always felt much the stronger technically for that position.

The fact that my colleagues on the panel talk about pushing the researchers to get it out, I think, makes my point. If you want the science pushed around to satisfy tomorrow's deadline of the regulators, that is what you will get with an in-house laboratory because those pressures will inevitably go right down the line as my colleagues have suggested they do. My view is that isn't helpful to good science.

It gets you a partial answer but leaves you in poor shape for the long term. When we want that kind of quick answer in the atomic energy business, we call up half a dozen or a dozen people who are as good as any in the world on that subject and get them together and they make their best estimates out of the depth of their experience and knowledge, and that is the basis on which you have to go with this afternoon's regulatory solution.

But if you want to do science and you want to really know what the answers are, the work will come along at the pace that capable people are able to push it and not one day sooner because there is some guy up here saying I have to have it.

Mr. WALGREN. Gentlemen, would you like to respond?

Dr. GOLDSTEIN. I think, actually, I am in reasonably close agreement with Dr. Hendrie on a lot of the points he has made. He is absolutely right that there is an inherent problem within a regulatory agency that will lead to a tendency to sacrifice long-term needs for short-term gains. But there is another side to that which I think is very positive, and that is that many of the long-term needs are really best identified by the people in doing research within the regulatory agency who are in close association with the research and who can predict these long-term needs.

Some of the problems—there is, for instance, recently Congress under RCRA passed a law which had what we call hammers. They had certain dates by which things had to be done. We basically took a laboratory and turned that laboratory around from what it was doing to do something else within a given timeframe.

Now, I would disagree with Dr. Hendrie that you can't rush the research. This is research that, because of the needs established by

a congressional mandate to develop the ability to model the rate of flow of materials through earth, this is work that was done much more rapidly and appropriately done, I think done with good science.

If we are going to talk, however, in situations where we are asked to do something for which the science is not ready, then absolutely correct. There is no way that you can, in a sense, get that science to move more quickly than it can. We need to know too many things. We can make some changes on the fringes, but by and large you are not going to move it more quickly than the science can move.

But in many of the areas that we are dealing with, the ability to do the work is there. It is a question of where you will put your resources for that work. In my experience in managing sciences and my experience in being someone who is a researcher being funded by Federal Government agencies, I can assure you that it is a lot easier to take a Federal laboratory and say, "Look folks, we have to drop what we are doing and do something else within your capabilities for that answer because Congress has required it," than it is to get outside scientists to do it.

One of the things that I was fascinated with is that laboratory—and this is a laboratory in Athens, GA, that was asked to do this—by and large responded very positively to doing that, to dropping what they were doing, something scientists usually don't like to do. Of course, they saw the real need for it, were given the attention and the funding to do this work, and they found it a very stimulating thing that needed to be done. They wouldn't have done it right then. They would have done it some other time.

So, that was a very positive experience, and I don't think it can be done elsewhere.

Mr. WALGREN. Mr. Jorling?

Mr. JORLING. I think Dr. Hendrie's first point is a large measure of the explanation, the different traditions of the two agencies. Without going into that history and the performance of the research and whether there are real differences in the kind of research that is done, I do think it is essential that scientific and research and development arms of an agency be as responsive to the mandates of Congress as is the regulating branch and that good management can bring that about.

Typically, EPA requires, unfortunately,—and this is not unusual to any administration; that is the way it is—2 to 3 years to take a Congressional mandate and put the first set of regulations into the Federal Register. My argument is that with the right kind of management and leadership, that effort can go on involving the science and the analytical people conjunctively and get to a reasoned and good public policy result.

Mr. WALGREN. Thank you.

We have to respond to this rollcall on the floor at this point. I would ask if you could stay and we will come back to you. There are a couple of areas that I know people who have thought about this have tried to direct our attention, and I might be able to raise some of that with you. So, if we could take a 15-minute break at this point and then if we can come back at that time.

[Short recess taken.]

Mr. WALGREN. Well, after that, I thought I had some great ground to cover and my mind is not up and running.

How do you reconcile what I hear Mr. Jorling saying that instinctively there is a short-term ability—Dr. Goldstein says the same thing—there is a short-term ability to respond to regulatory problems if the resources are directed in that direction, and what has apparently been said to be a failure of the regulatory agencies to develop a longer-term basic research program are these two different things that should be done? Regulatory agencies, I guess, should do both?

Is there reason to have these very separate so that perhaps you can force the interface with the one but perhaps have some of the separateness that Dr. Hendrie emphasizes with the other? Are we properly criticized for being too short term in the regulatory research programs? Is there a basic inconsistency between doing both? Is there an ability to do both?

Can I ask for brief reactions to that thought?

Dr. GOLDSTEIN. Let me in a sense try to put an additional dimension on the question you are asking, sir. I think there is a need to do both.

From the EPA's point of view as responsible for EPA science and technology, it was important to recognize that in certain areas, such as in health, EPA's health research is a tiny, tiny percentage of the overall health research done in this country. If EPA's health research disappeared, the Federal health research would not notice it. EPA would notice it.

On the other hand, if you get into something like atmospheric transformation, if you get into an area such as ecology, effects of pollutants in estuarine areas, EPA had a major portion, a significant percentage of total Federal and total, in fact, U.S. research in that area that it was supporting.

It was much more important for EPA to be doing long-term research in those areas in which it was, not the only player, but a substantial player than it is in those areas where EPA is not a substantial player in the totality of that type of research. So, the answer is yes, both are needed, but the degree to which we need both will depend in part upon the resources that are available in the total U.S. research effort.

Mr. JORLING. They are two different functions, and I believe that the short-term one, the one that is under the mandate from Congress, is the more important one for EPA to be carrying out. However, I strongly support a portion of EPA's R&D effort being devoted to long-term research.

I would qualify that, however, by saying that participation in the short-term processes of the agency enable perception of and identification of the most likely important areas for long-term research more than just sitting back as a group of experts and trying to anticipate what the long-range needs are. They can be drawn out of the short-term processes much more accurately, much more relevantly than they can otherwise.

Once you recognize that, I believe an agency like EPA should have a residuum, under the direction of the R&D arm, which is devoted to long-term research. In EPA's context, however, I don't think that would be a very significant proportion of its research.

Ten percent would be a nice target. It is below that right now, I think.

Mr. WALGREN. That would vary from agency to agency, I gather, depending on their role?

Mr. JORLING. Yes.

Dr. HENDRIE. Mr. Chairman, I think there is no question that a regulatory agency needs both. In the atomic energy business, we have always pretty well separated them. At the NRC, we had a major research program under an Office of Research that was engaged in long-term, more basic and thorough-going reactor safety studies and associated science and technology to support that.

The short-term assistance to the regulators and the licensing staff came under the heading of technical assistance. Those people in the agency had contract authority to establish contracts with anybody they thought was competent to help them and that work they ran themselves. That we regarded as just what its title implied—technical assistance to the regulatory and licensing staff. That was of a short-term response to the problem sort of enterprise.

But for the most part, I don't regard much of that as science in the sense that I think you are talking about it here. The science in the NRC is almost completely over in the Office of Research, it is long-term, and it needs to be done by people who keep their minds on those long-term projects.

Mr. WALGREN. Is there a difference in the importance of these agencies having their research in-house versus contracted out? Would that be something that you would agree that you would find most appropriately substantially different balances from agency to agency, or can you categorically say that you prefer the capacity in the organization or essentially contracted out?

Dr. HENDRIE. I think I will say categorically that I think it is better if you contract it out simply because you can go to the best people for a given piece of work, and you are not saddle with a certain number of slots which are labeled research who are there year in and year out, immovable as the Federal personnel policies make them. Once you get them, you have them for life unless they decide to take themselves off.

On the other hand, you must recognize that I speak from an experience that is totally the other way. It is my view that it is the better way to run it, and it is my view that EPA could very well have established a contract research program in the beginning and developed a set of people in the universities and in research institutions and all around the country whom they dealt with principally and things would have gone just fine.

I remind you again that is a view which is based on my own experience in that kind of system. So, you have to take the answer and weigh it with that background and prejudice in deciding what is best.

Mr. WALGREN. Well, let me ask Dr. Goldstein. You indicated in your testimony that you felt that EPA had lost a certain amount of flexibility particularly on the question of where the research was to be done. What led to that? What lies behind that problem?

Dr. GOLDSTEIN. That really is a bureaucratic problem, sir. I have no real difficulty with the basically 2-to-1 split in favor or extramu-

ral versus in-house research that the budget has given us in the past few years. I might prefer it to be 60–40 but it is an appropriate range. Most of EPA's research is done extramurally.

But because of the fact that really micromanagement has been performed by congressional staff, OMB, within the agency on controlling the way the budget is used, there simply isn't an adequate amount of money to fund the 1,800 people who are provided to us under the budget. So, we don't have enough money to buy our rats. We don't have enough money to—I say we as if I am still there—but there is an inadequate amount of money to really do the research that has been budgeted agreed to by Congress and the executive put in there, and it is because of a budget process that is inappropriate.

I can go into it in great detail if you wish. Perhaps let me just say one other thing. The way the budget is made, there is an internal salaries and expense budget. Only in EPA is that budget, which is under congressional wording of the resolution for managerial purposes, only in EPA is that also for in-house research.

There is another budget called research and development. In NASA, for instance, they use that research and development in-house or extramurally as they feel warranted. In EPA, we must use it extramurally. We cannot use it intramurally.

The net result is that since you must pay the 1,800 people, you must pay the money to keep the laboratories open, the amount of S&E that is left over after you have done those two necessary things is the amount of money you have to buy your rats to do the other research needs. And that has been grossly inadequate, and it has been going down. So, during my tenure at EPA, starting at $230 million budget now being over $300 million R&D budget, I actually had a decrease in the amount of money available for those scientists who were doing in-house research simply because of the sort of backward way that that Research and Development Program was put together with this unnecessary degree of micromanagement.

Mr. WALGREN. You used the phrase to buy your——

Dr. GOLDSTEIN. To buy the rats. Experimenters have to buy rats.

Mr. WALGREN. Oh, to buy rats. I see, a generic term.

Mr. Jorling, would you like to comment at all on that?

Mr. JORLING. One of the things that we all deal with in public life is that we are saddled with a bit of history and it is not possible to look at the blackboard as if it were blank and recreate an ideal scientific research and development arm that would be applicable to all agencies. We are stuck with the histories of each of these agencies.

AEC started with a very different history, especially with respect to science and research, than did EPA. When EPA was formulated in 1970, it was an amalgam of several other agencies and the laboratory structures that were in those agencies came in to form the basic structure of the EPA Research and Development Program.

So, there is a different history and any changes which I would call should be directed more at incremental improvement rather than trying to recreate a nice new structure that might be nice for the tidy-mind syndrome but wouldn't really reflect these different histories.

On the contracting out, I indicated in my prepared remarks that I am very negative on that, partly because of what I consider to be inherent conflicts of interest that exist in our context which is different than the context of NRC's laboratories which are, while they are contracted out, they are in effect a sole-source entity out there and a lot of what they are avoiding are salary limitations so that they can pay their scientists much higher than the civil service can pay them. But they still have some attributes of responsiveness that the contracting relationship that EPA uses is not available.

So, there are those kinds of differences.

The contracting procedures, the contracts themselves make it difficult to change anything that is going on as change is perceived to be needed by policymakers. So, there are a series of reasons why contracting out is insufficient.

I would shift the percentage the other way. I would go 60–40 the other way if EPA had sufficient in-house personnel to manage those contracts, manage them in more than just a paper volume sense but actually manage them to make them responsive to the needs of the agency. But right now, I don't believe, certainly it was the case when I was at EPA, that the agency had sufficient personnel to make sure that those contracts were delivering the kind of service that the agency needed.

So, there are a lot of impediments, but I tend to believe that the agency can attract the best and the brightest even within a restricted salary structure and that is not a real impediment.

Mr. WALGREN. You all sort of indicated an approval of the distinction between risk assessment and risk management and the separation—or perhaps I am putting words in your mouths now—but someone touched on that and I thought there was something supportive said in that direction, the one being a purely scientific risk assessment and the other being a political question of risk management.

How good is our risk assessment? Does it really give guidance to those who are then proposing methods of management?

We had a bill up here in this committee that was intended to try to stimulate some thought on that, and on the question of what a model risk assessment should look like. You get the feeling that the assessments are often simply the supportive opinion for whatever conclusion somebody wanted to reach.

Can you tell me where we are on risk assessment and are there separations that can be made effectively between assessment and the response to it that we could receive in a way that you could distinguish between the two and perhaps reach different conclusions from it?

Mr. JORLING. I will respond, Mr. Chairman, just by suggesting that I could submit for the record an article I have written on that precise subject and defer to that. I think it is better expressed there than I can do orally.

Mr. WALGREN. OK. We are certainly interested in that.

[Article by Mr. Jorling follows:]

Risk Assessment: Dissent from a Former User

By Thomas C. Jorling

In the dynamic area we call public policy, new themes and new words and phrases emerge frequently, though usually in unpredictable ways and with uncertain impact. Sometimes these changes in our rhetoric reflect new thought, new ideas or new concepts; sometimes they merely represent, as it were, a new name for rose; sometimes they are a little of both. Risk assessment and its corollary risk management, while not new terms in the strict sense, are certainly new to the public dialogue in environmental protection. There may be some new substance behind the term risk assessment, primarily as a function of the whole representing something more than the sum of its parts, but the words do little more than provide a new lens through which to look at old, reliable, in the sense of constancy, environmental and health protection concepts, policies, and issues.

Just the fact of changing words and phrases — even before we look behind them to what they describe as I propose to do on risk assessment — can operate to real effect. For instance, new words can attract new interest, or rekindle old interest in a continuing problem. The press may cover a story on "risk assessment" when they wouldn't be motivated to cover yet another story on "pollution control." However, on the other side of this two edged sword, a change in words can provide an affected interest with another bite at the apple, as for instance, when a statute, directing pollution control more tightly than an affected interest would like, might be revisited under the guise of this new thing — risk assessment. Of course, this is, in one sense merely being clever in the competitive processes of public policy development.

But we shouldn't lose sight of the fact that a change in the semantics of public dialogue is rarely benign in effect, if not in intention.

One would gain the impression from reading both the popular and trade press and even the scientific literature that risk assessment is an overarching concept that includes within it all aspects of environmental protection; a new paradigm. As such an impression, it is wrong. Risk assessment is a tool, but in the sweep of issues that flow from the relation of Homo sapiens to each other and to the environment, it is — and should be — a limited one. In this article I propose to examine what risk assessment is, and isn't, from three perspectives; first, its use as a conscious and unconscious diversionary concept; second, its limitations when used in public policy processes; and third, its pragmatic and important use in the traditional decision making process.

Among the primary obligations of the governments' of industrial societies is the establishment of policies and programs that assure the integrity of the structure and function of the life supporting biosphere into the foreseeable future. A future that should extend at least as far into the future as we can see our past — several hundred years. Risk assessment as a policy does not contribute materially to that fundamental objective. More significandy, to the extent it is held out to be such a policy, it diverts attention, and more significantly, effort from the primary objective.

Risk assessment is premised upon and assumes the release of chemicals to the environment. As a general principle describing the dynamics of industrial society that is a flawed assumption especially when considered from a perpective of hundreds of years. A policy of reacting to releases after they occur, in a society where chemicals are introduced at a rate of several thousand per year and where quantities of production have grown from mere millions of pounds of production in the 1920's to over 400 billions of pounds currently, is simply irresponsible. There may be situations where a given chemical "must" for compelling reasons be released, but to assume all chemicals can be subject to risk assessment and then released at an acceptable rate runs into the face of the complexity of the dynamics of public health, much less the complexities of ecosystem dynamics.

Thomas C. Jorling

The overarching quest, the guiding policy, must be to prevent release, to move industrial systems in the direction of closed cycle production, recycle, reuse and confined and contained disposal of pollutants. The challenge to our production engineers and our product developers is to create ways to prevent release through such principles as separation of production processes, change in processes, conservation in the use of matter and energy, segregation of waste streams, and source control. We can over time and economically achieve these results. For instance, under Clean Water Act program of effluent control more than fifty industrial categories have reached elimination of discharge.

Even in the area of combustion, while there will be releases of carbon dioxide and water that, especially in the case of CO_2, may cause disruption of the life support system, fuels can be cleaned, combustion process and facili-

Thomas C. Jorling served as Assistant Administrator of the Office of Water and Waste Management of the U.S. EPA under the Carter administration. He is presently director of the Center for Environmental Studies at Williams College.

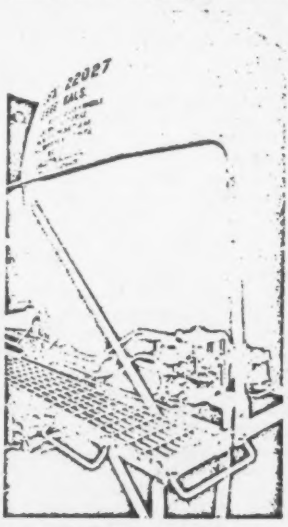
"Risk assessment is premised upon and assumes the release of chemicals to the environment. A policy of reacting to releases after they occur is simply irresponsible."

ties can be engineered, and recovery systems can be installed to prevent release. The notion that a rapidly increasing, rapidly industrializing 4.5 soon to be 7 or so billion people can acceptably load the biosphere with chemicals is not only wrong, it is unnecessary. An automobile, if designed at the outset for the recovery of components at the end of its useful life could easily serve as a source of metals, plastics, and fibers for the next generation. In addition to preventing the release of chemicals to the environment, this pattern of product use would abate the tremendous waste that is characteristic, so far, of all industrial societies.

When the Administrator of EPA — even if unintentionally — carries forward the message that the basic role of EPA or the Government is to conduct risk assessment and its corollary risk management it diverts our energy from the basic responsibility to move toward a society structured and functioning as if there is a tomorrow. In my view, the response Mr. Ruckelshaus has received from such sources as Mobil Oil Corporation praising risk assessment[1] is a manifestation of this diversion. As representative of corporations charged with the duty to act in the best interest of the corporation, Mobil does not want to spend in the interest of the future of society. Mobil recognizes risk assessment assumes releases of pollutants, and that with their expertise they can in all likelihood demonstrate "acceptable" risks associated with their pollutants. I will say more about these implications in the second part of this paper. The diversion, however, has worked. It has shifted the focus to risk assessment not as a tool, but rather as the end. It makes it all the more difficult to organize ourselves in a manner that will assure a long-term sustainable society. Our intellectual genius instead of being applied to avoiding releases of chemicals to the environment will be caught up in the never ending task of figuring how much chemical, in a world of an ever expanding increase in the manufacture and use of chemicals, can be packed into the environment with acceptable risks.

II

The new EPA Administrator, William Ruckelshaus, has made risk assessment and management a central theme in his effort to put distance between himself and his immediate predecessor, Anne Gorsuch Burford. Understandably, Mr. Ruckelshaus needs to change the dialogue concerning environmental protection if he is to reestablish any credibility for EPA and its mission. In his campaign, with addresses to the National Academy of Sciences, and articles published in such distinguished Journals as *Science*,[2] he is attempting to seize the



A rail car designed to reduce the risk of accidental chemical spills.

high (rational) ground and his weapons are risk assessment and risk management. He describes the concepts:

> "The formula should be as precise as possible and should include a responsibility for assessing the risk and weighing it, not only against the benefits of continued use of the substance under examination, but against the risks associated with substitute substances and the risks associated with the transfer of the substance from one environment medium to another through pollution control practices."

and a little later on:

> "Scientists assess a risk to find out what the problems are. The process of deciding what to do about the problems is risk management. The second procedure involves a much broader array of disciplines and is aimed toward a decision about control.
>
> In risk management it is assumed that we have assessed the health risks of a suspect chemical. We must then factor in its benefits, the costs of the various methods available for its control, and the statutory framework for decision."[3]

While there are exceptions in its actual applications, such as in pre-manufacture review of chemicals under the Toxic Substances Control Act, most applications envisage by the Administrator are to ongoing activities or often to activities that have been initiated that result in the release of chemicals. While the words risk assessment are new, when applied to such situations, they, in fact, describe what is an old pollution control concept — that of ambient control strategy such as that represented in general by the Federal Clean Air Act. That is, find out (who?) how much of a chemical we (this or that generation?) can accept in the environment, to take advantage of the benefits of the use of such chemical (what is the value of a few lives lost?), then apply and maintain controls to achieve that level of release.

Risk assessment and its semantic antecedent, an ambient control strategy, share many flaws when advocated as a public policy that need to be understood. First of all, it puts the entire burden of proof on the government, on the public and the environment to support control.

It is not just a burden of proof in a legal, evidentiary sense. It is a burden that is made exceedingly heavy by what it in fact assumes. It assumes an ability to acquire knowledge about the release of chemicals, their transport and fate throughout the biosphere, their effects throughout the myriad of organisms in the biosphere, over time, and ability to evaluate possible synergistic effects. If we are concerned about the health of persons, then we must in addition incorporate all of the uncertainty on how and why chemicals reach, and then effect the structure and funciton of a human organism, an organism

"When the Administrator of the EPA carries forward the message that the basic role of government is to conduct risk assessment and risk management, it diverts our energy from moving toward a society structured and functioning as if there is a tomorrow."

already immersed in an environment with countless chemicals in countless circumstances. But risk assessment all sounds nice, because as the Administrator assures us, scientists do it. And before you make a bumper sticker out of the preceeding — the phrase "for money" should be added.

Each of these elements of the burden of proof deserve attention. The ability to acquire knowlege about the release of chemicals into the environment assumes a monitoring and analytical methodology that is not, nor will soon be routinely available. Whether in air, water, or solid waste streams we generally only sample for the most gross parameters. Where a given chemical is targeted, specific methods and protocols must be tailor made — always with the burden on the government, constantly scrutinized and contested by the affected interests. It's one thing to say scientists do it, it is another to ask whether they can.

Once released, understanding the pathways by which chemicals move through the biosphere, how they interact and with what effect on organisms is assuming that we can know in detail what many ecological scientists believe is a system — the biosphere — that is more complicated than we can think. Yet, if we assume the release of chemicals — we willingly take on that burden.

Time, and the effect its passage causes as chemicals are released and move through the biosphere is over the edge of uncertainty. We may know what a given chemical exposed to an organism or community of organisms does in one day or one week or one year, but we know precious little what it may do after ten years. Yet, such an understanding is implicit in carrying the burden of proof in a risk assessment that may lead to the authorizing of the release of certain concentrations of that chemical for many, many years.

Synergistic effects, that is the action of one chemical as it may be influenced by the action of others — probably hundreds of others — is currently outside of our understanding. We generally caveat any statement about a chemical subjected to risk assessment by simply stating we do not know what the synergistic effects are, if any, in any of the countless situations as a given chemical moves through the biosphere.

These limits, or perhaps better elements of the burden of proof take on added importance when the target organism of the risk assessment is the human organism. The use of risk assessment as an overriding policy as it appears the new Administrator is urging when he advocates the modification of the Nation's environmental protection statutes to incorporate risk assessment as "a common statutory formula for accomplishing our tasks"[4] necessarily involves the ultimate experiment — it would use the American people as a population of experimental animals. Since we do not use humans in direct exposure experiments, we rely on surrogate animal and other tests (and often the regulated interests strongly oppose these tests). Scientists simply can not do more than estimate risk. Risks deemed acceptable by such methodologies are then tested on the people.

With these and many other uncertainties and weaknesses inherent in risk assessment, the problems for public policy are compounded when we move to the application of risk management, which is basically the application of benefit-cost principles to decisions on whether, and to what level, a release of a chemical should be controlled, i.e. the determination of an end, not of means.

There are many criticisms of benefit-cost methodologies, especially when applied to make choices among ends, rather than among means. I will not repeat those but add some that are not so common.

Let us look at some of what I believe to be essentially related implications of risk management with its necessary inclusion of benefit-cost methods. Mr. Ruckelshaus describes it as follows:

> "in risk management it is assumed that we have assessed the health risks of a suspect chemical. We must then factor in its benefits, the costs of the various methods available for its control, and the statutory framework for decision."[5]

It is argued by the proponents of such analysis such as Murray Weidenbaum, President Regan's first Chairman of the Council of Economic Advisors, that it is "a neutral concept: the same weight is given to a dollar of costs as to a dollar of benefits."[6] This notion that all aspects of life can be reduced to the same measure — a dollar — is neither neutral nor objective. Rather, it flows from a preceeding ideology — about which more will be said later — that humans are motivated *only* by that subset of activities that generate monetary wealth.

It does not take an extraordinary display of human judgement to conclude that a five dollar heart pacemaker component is not "worth" the same as a five dollar can of deodorant, or that an issue of *Governance* at $3.00 is "worth" the same as an equivalently priced issue of the drug cultures publication *High Times*. However, once those numbers are entered on the benefit-cost ledger they are rendered "equivalent."

But this dogma of faith — or fiction — that everything can be compared through the measure of dollars is compounded in its effect by the systems or methods through which it is applied in so-called analysis — and further removed from human judgement. Increasingly, the analysis part of risk management is performed by the computer — which even if humans can't agree on value — *must* compare everything — apples and oranges — as if the dollar does in fact compare the value of everything. And in the end, it punches out those all too intimidating printouts: "see, its right here in the numbers, the benefits outweigh the costs." Human judgement is avoided in relying on the hard, objective numbers — "the bottom line."

We can distinguish the type of benefit-cost analysis used, for instance, in choosing among building materials. There it makes good sense, it is being used as a tool to assist in a choice between means. This brick with a cost of such and such and benefits in terms of strength and durability versus another competing material. But to compare dollar benefits to the economy of the chemical XYZ used in making eye shadow against the dollar costs of a slightly increased cancer rate in the society cannot by any mixmaster, cuisinart or not, be made the same.

Photo courtesy of EPA.

EPA technicians remove a sample of hazardous waste from leaking drums.

Wendell Barry has put it more succintly: "The viciousness of a mentality that can look complacently upon disease as "part of the cost" would be obvious to any child. But this is the "realism" of millions of modern adults."[7] Charles Dickens said a fool is some one who knows the price of everything but the value of nothing.

Another, and not benign element of the ideology that must be evaluated in considering the efficacy of the application of risk management to broad questions of public policy is the general underlying premise that whatever increases monetary wealth is inherently to be preferred over those things, activities, or experiences that do not. And it is not only preferred, but induced by such analysis. So that directing effort to caring for a retarded child, for instance, appears irrational to benefit-cost analysis especially compared to a professional baseball player or even a drug dealer. Not only does risk management incorporating benefit-cost analysis favor strongly wealth creating activities, in the sense it gives them more "votes," it also strongly favors, also in the sense of giving them more "votes," those persons, real or artificial, and activities that possess, control, or involve large amounts of resources that are, or are easily converted, into dollars. Thus, for instance, any constraints on highly consumptive lifestyles, such as frequent flying would represent a huge cost, while restraining the use of automobiles by the poor would not, or improving controls in a chemical factory would represent a large cost, while the value of the health of people in the ghetto would not. If everyone had the same number of dollars it may be that — as in the one man one vote democratic theory — the use of benefit-cost analysis would represent an approximation of how persons valued different courses of action, but they don't and it doesn't.

Since risk management represents a systems technique it is useful to raise another concern that flows from the rigidities created by systems phenomena. Benefit-cost analysis is advocated as technique for evaluating an action or a proposed action in our dynamic sociopolitical system. If benefit-cost analysis becomes the formula applied to public policy decisions as advocated by a broad spectrum of economic theoreticians and practitioners ranging from William Nordhaus, a Yale economics professor and former economics advisor in the Carter administration, commonly identified as a "liberal" to Murray Weidenbaum, identified as a "conservative," then it would assure that our system would not change its basic orientation for, by definition, any change in the system would be an unacceptable cost. We can be thankful that the Declaration of Independence and the Constitution, much less the recent Civil Rights and environmental and health protection successes preceded this new methodology. It is unlikely any would have been produced, only if the benefits exceeded the costs.

The driving orientation implicit in benefit-cost analysis — is, simply put, the maximization of material greed. It measured all things in terms of dollars and since the unit of comparison can and does grow, it follows that those activities or behaviors which lead to more dollars are going to be the activities or behaviors that the method of evaluation will favor — nay, by its own terms it will serve, in a vindication of B.F. Skinner, as a reward to elicit that kind of behavior.

Adopting a system that reduces all features of human actions and values to expression as a unit of commercial value *necessarily* degrades those actions and values which do not contribute to an increase in those units. Merely being in good health does not, nor does love, nor brotherhood, nor appreciating beauty. Over time in such a system therefore, the relative value of those characteristics must decrease. A benefit-cost system will certainly produce an efficient commercial machine, and those human values inconsistent with that result will, per force, be eliminated in the process.

The protective regulations under mandate from Congress flow from a sense of justice and compassion, from a principle that it is wrong for innocent citizens to be exposed to threats by

"The people will understand and accept risk, not when government is acting to protect the activity leading to the risk, but when the government and the authority causing the risk are moving to eliminate it."

activities over which they have no control, and in many instances, of which they are not even aware. It was a response of society that emanates from a traditional view that the welfare of human individuals, all human individuals, is the primary reference measuring all activities.

But now regulation is a practice subject to criticism and challenge on many grounds. I am not referring here to the criticism that regulations can be made somehow 'better' or developed with less reliance on red tape. I am concerned with a popular assertion, and an apparent 'cause' of this Administration, that such regulations should be applied only if benefits outweigh the costs. Sometimes explicit, but always implicit in such a premise is the result that previously considered "inalienable rights" are now subject to being commercially valued and then lossed or gained as a consequence. Life itself would be valued and while the exact identity of those who will suffer death is not known, especially to the practitioner of the analysis, the death of real human individuals will occur.

Some argue this phenomenon is simply an inescapable consequence of modern, technologically-based societies. But cutting away all the rhetoric, this reduces to a view that technology doesn't serve humans, humans serve technology and its imperatives. It is as if the relatively benign feelings of the B-52 pilots causing untold and unbearable destruction from their plush offices high in the sky are an inescapable and presumably better aspect of high technology, while the feelings of the G.I. pulling the trigger on a proximate and recognizable human are mere relics or artifacts of the past. In many ways benefit-cost analysis performs the same role as the B-52. It immunizes from human relationships by placing distance and technology between action or decision and consequences.

III

This then leads to my third point. Risk assessment is a valuable public policy tool and is, and should be, used as such. It is not, in my view, an overall strategy or goal for environmental protection.

Administrators must decide among the very large universe of problems contesting for attention which ones should receive attention and especially attention in the form of scarce resources. Frequently, EPA is faced with choices such as should it apply its resources (R&D, regulatory, financial, staff, etc.) to this or that chemical, this or that geographical area, or this or that hazardous waste site. Risk assessment is a most necessary tool in informing that decision.

Similarly, in any real world situaiton prior to achieving closed cycle production and recycle, reuse of materials, EPA and other agencies must make judgements on interim levels of control or protection to be achieved. Risk assessment can guide, not make, that judgement. But, readers must be saying, this sounds very much like the Ruckelshaus' articulation of risk assessment. And so it does. In the day to day life of environmental protection these activities do and should go on. They have been going on since the beginning, we just now call it risk assessment. And when it does go on it should go on with the best science, the best analysis, and, of course, the most open and candid communication with the public. On these points there is no disagreement.

The dissent from the Administrator's view comes at the next stage — the stage of risk management — where the practice becomes not just a tool but the objective — i.e. to define acceptable risk from a given practice as the end point of environmental protection. It is no wonder that many responsible for the release of pollutants, such as Mobil, become supporters, when risk assessment/management take on this character. But, as I have tried to point out, risk assessment must take place in an overall policy of achieving chemically tight industrial societies. We must force continued development of industrial processes that don't release chemicals, of products that can be recycled, and of wastes that can be contained. National policy must force technology to these objectives, not as a risk assessment and management policy necessarily does toward an objective of dictating for the public an acceptance of risk for all time.

In my view the people will, for a peroid of time, accept a risk, identified by the government if they have a credible belief, one, in the competence and honesty of government and, two, that the overall program under which our society is operating is designed to avoid that risk. The people will understand and accept risk, not when government is acting to prorect the activity leading to the risk, but rather when the government and the authority causing the risk are moving to eliminate or further reduce the risk.

Put in a more immediate context, the people near the Tacoma smelter may accept, or the government may impose, a risk after the installation of the best control and process technology if the smelter and the government have underway a meaningful (i.e. real research dollars) program to improve the smelting process and the technology of control and that the decision on the level of control will be revisited in five or so years with improvements in control or process, if any, then imposed on the plant.

To summarize then. Risk assessment and management is a valuable tool in making decisions on what to do at any point in time, or on what chemicals or activities to focus scarce resources. It should not be an overall policy for environmental or public health protection. If it becomes so we will have lost an opportunity to work toward an industrial society structured and functioning as if future generations make a difference and if such concepts as life, liberty, and the pursuit of happiness are to continue to have real meaning. □

NOTES

1 "An Invitation Too Good To Refuse," an oped ad of the Mobil Corporation, New York Times, October 15, 1983.

2 Ruckelshaus, W.D., *Science, Risk, and Public Policy*, Science 221: 1026(1983).

3 Op cit at 1027.

4 Op cit at 1027.

5 Op cit at 1027.

6 Weidenbaum, M.L., *"Weidenbaum Analyzes Benefit-Cost Analysis."* Across the Board, February, 1982, p. 70.

7 Berry, W., *"The Unsettling of America*, Avon, p. 18 (1977).

Mr. WALGREN. Are there any other thoughts on that?

Dr. GOLDSTEIN. Having spent a fair amount of time in the past few years working on this question, let me just briefly if I can give you an overview of my view on it.

I think risk assessment is a very valuable tool, but a tool for the regulatory process. Like any tool, it has its limitations and the best use of it is made when the worker really understands how to use the tool.

We have had some problems with it. I have been amazed sitting in at decision meetings where there have been three numbers on a blackboard. One is a risk assessment number of, say, a body count. Another has been an economic cost of doing something about that. The third has been a guess as to what the economic costs would buy you, what the control would buy you in terms of decreasing the exposure. There are tremendous arguments about whether that risk assessment number is correct or useful.

In fact, there is a lot of uncertainty about that one number put on a blackboard, but I didn't find it any more uncertain than those other two numbers, the economic analysis, that guess as to how much control you would really buy if you put on this new installation or new device or tailpipe or whatever it might be.

So, in the context of the need for a regulator to make a decision with the kind of number that regulators have with which to make decisions, I find risk assessment to be very useful. Now, in the context of is there actually going to be 37.37 people dying each year because of this particular pollutant at that particular level, obviously that is not an exact number and obviously it has many difficulties, but I don't find it having more difficulties than other numbers.

In terms of the risk assessment and risk management separation, the need to keep the risk assessment from being the number that the risk manager wants to get which I think is crucial for the success of this, it can be done. At EPA, we have tried to come up with guidelines on how to do risk assessment. The guidelines are the best available science that we know now. They are not only logical in that sense, but they are explicit.

If you follow those guidelines, you will come out with an answer. If you don't follow those guidelines, you explicitly have to explain why so that if, in fact, the scientific community will agree with it, that is fine. If not, you basically can appropriately be accused of distorting the process.

So, in general I find that separation can occur. Guidelines are useful, and it is valuable. The separation is not complete. The risk assessment process in terms of hazard identification, quantification of dose response, exposure assessment, they can be separate from risk management.

But when you take all those numbers together you get a risk characterization. How you characterize that number that comes out starts to get into the risk management point of view. As a physician, I do this all the time. There is a test that has a 1 percent incidence of side effects. Do I say to you, look, if you take this test there is 1 percent chance you are going to die of it, or do I say to you it is 99 percent free of risk?

That is a characterization that can also be used in the risk assessment process and the end point of the risk assessment process which we have to be careful with. There is also more to safety considerations where it is not clear whether that is risk assessment or risk management, to what extent a margin of safety fits into that. But, by and large, you can keep them separate.

Mr. WALGREN. The concept of risk characterization, is it right to think that there are some circumstances under which there will be a certain number of bad results? You don't know which individual result will be a bad result, but there will be a certain number of bad results. Does that characterization—is it fair to say that is one kind of risk, a risk where we don't know whether any individual will be harmed or have a certain effect but we know some individuals will and we can make a pretty educated guess about how many individuals will and that is one characterization.

Another characterization would be the possibility that some will. Maybe none will. In my mind, I keep flipping in and out on those two where in one instance, there is a short straw in there and we just don't know who is going to pull it. In the second instance, we don't know whether there is a short straw in there but there might be.

Does risk assessment differentiate between those two kinds of——

Dr. GOLDSTEIN. Yes; and I think you have phrased it very well. The hazard identification process, if you will, allows us to say there is or is not a hazard there. When you can say there is or is not, that is fine, but when you say there may be a hazard there, that is a problem.

What we did at EPA in the last year or two is to put a letter next to the risk number we get out, the letter indicating whether this is known to occur, suspected to occur, possibly might occur. We can use different adjectives. But how you characterize that, as you have just done, is part of the risk characterization process once you have that information. Obviously, how you present it to the Congress, to the public, to the regulators is going to make a difference in how people respond.

What we feel is important from the risk assessment, from the scientist's point of view is that we be asked to always present it in the same way, but that really, if you will, it is the managers' role to tell us what is the way that they want it presented so that you always do it the same way across all different types of chemicals and situations, and we don't one time present it one way and another time present it a different way, one time say it is 99 percent and the other time say it is 1 percent.

So, we have asked for that type of help.

Mr. WALGREN. Dr. Hendrie, is there anything you would like to add?

Dr. HENDRIE. To your basic question, Mr. Chairman, I think risk assessment methods have been developed and improved substantially over the last 20 years and they are getting to the place where they are very useful. It is still an art which depends in part on the skill of the practitioner, and that is a human variability that you have to be very careful about. But I think one can make in a number of technologies and in a number of areas there are meth-

ods of doing risk assessment that give you a much better handle on what the risks in that area really are than any other way that I know of approaching the problem.

In particular, risk assessment methods are a very useful way of disciplining your approach to a problem to try to keep you from omitting things on the one hand or giving undue emphasis on the other to a certain special aspect.

Risk management is what we are doing in safety regulation. Safety regulation, in my view, is intrinsically an exercise in risk management. So, they are separate but they obviously have strong relations.

As has been pointed out by my colleagues here, once you begin to talk about an area in risk assessment terms, you begin to create a language and a way of thinking about that area which is almost certainly going to be reflected in the risk management in the regulation area.

Mr. WALGREN. Well, I am intrigued with the difference in the character of those risks in that politically, I believe, these days you often hear nothing is risk-free, therefore justifying the individual to run a certain risk. But from a public responsibility level where you really are responsible for the whole, there is a very real difference between—it becomes irrelevant or relatively irrelevant whether any individual is running a risk. The real question is what is the certainty of the harm in the aggregate.

If you have a problem where there is certain harm in the aggregate, it seems to me that we should approach that very differently from a problem where we only have possible harm in the aggregate. Yet, I hear arguments that, from my opinion, are urging the public that, look, nothing is risk-free; therefore engage in a pattern of behavior which, although we said it isn't risk free, it was only risky to the individual; it was certainty to the aggregate.

Dr. HENDRIE. I don't find the dividing line that you seem to find, Mr. Chairman.

Suppose I know that exposure to ionizing radiation produces—I have a statistical basis for believing that there is a connection between exposure to ionizing radiation and certain latent forms of cancer. I have determined within the limits of error of my statistical analysis that we will get a cancer with every 5,000 man-rem of exposure in the population.

However, the uncertainty range on that result runs from 0 to 2 cancers. It may be 0. Nevertheless, I have a frequency distribution which says the likelihood that I will get 1 cancer for 5,000 rem is higher than that I will get 0 or I will get 2 or any higher number. There is a frequency distribution, and in deciding what policy ought to be with regard to ionizing radiation exposure, I can look at the frequency distribution which includes 0——

Mr. WALGREN. Why does it include 0? It may very well in that instance, but are there instances where you might be more likely to get 5 and your uncertainty range runs from 2 to 7?

Dr. HENDRIE. Well, in this case it runs from 0 to 2.

Mr. WALGREN. Yes, but hypothesize with me an instance where it ran from 2 to 7. You could step back and say you are sure you are going to get 2; you most likely get 5 and you might get 7. That

is a different circumstance than the circumstance that you raised as an example where truly you could say we may get none.

I am wondering, in the regulatory business, are there these two kinds of circumstances or have I made one up?

Dr. HENDRIE. I dare say there are some places you find where you could say my assessment, even though my precision is not ideal, there is a frequency distribution in what I understand about the phenomena, but I have very high confidence that there will be some effect, that is, that the wing going toward low values either doesn't get to 0 or when it gets there it is a diminishingly small likelihood.

But I suspect that there are also an awful lot of areas where the wings of the distribution on the low side go in fact down to 0. They certainly do for low level radiation. There is no question about that.

Now, what do you do about that? Well, you look at what the distribution is and say, look, the most likely value, the place that it looks like a more probable result lies isn't at 0. It is up at 5,000 rem and there is an effect and we will now take regulatory steps and establish some requirements that take that into account.

You do the same if the center of the distribution is up at 5 or 7 or wherever you like. So, the fact that the wings go out to 0, I don't find that creating a qualitatively different situation to deal with from a safety regulation standpoint.

Mr. WALGREN. I see. Are there any other thoughts on the same situation?

Dr. GOLDSTEIN. No. I think in a sense the kind of problems that we know of that we can definitely identify a number are, unfortunately, the easier ones. You ask me if we put the mall into wildflowers how many people would come down with hayfever or asthma attacks from the pollen, I can come up with a number, and I can assure you it won't be 0. Workplace allergens, seatbelt rules—we know that there will be people dying in automobile accidents no matter how we alter that risk.

But most of the chemicals that we deal with that are uncertainties and where there is major argument about them, the probability distribution goes down to 0. For a lot of these, at the levels that are present after we have regulated the bad ones which we have already done, the possibility that there exists some threshold, some tiny amount above which you must go before you are going to get any cancer or some other effect is still there. We will not solve that question until you have mechanistic understanding of how these compounds work and we are still a little bit away from that on a lot of these compounds.

So, unfortunately, the probability distribution goes down to 0.

Mr. JORLING. There are immense political differences in the way it is characterized, and I think that is what you have put your finger on. Because there are some fundamental questions that must be raised ultimately about those characterizations and who makes which decision and on what basis do they make it, that is why I say there is only advocacy science in rulemaking.

If I took the wing out at 0 and was representing someone who did not want regulation, I could characterize that in a way that would attempt to persuade a decision maker not to regulate as

stringently as they might if they characterized the probability at something greater than 0. So, that is where the advocacy science is used, and it is used to make a point. It is used to represent a position on an issue.

The other thing that I think you are getting at is when the curve doesn't go to 0, what is the situation as it presently stands? Then you ask the question, how much is it worth to avoid that exposure or that risk? And who makes that decision?

Right now, agencies make it. I made it. Dr. Goldstein has made it. Dr. Hendrie has made it, and we make it inconsistently. Perhaps that is the way it should be, but if you look at EPA's regulatory decisions in that situation, they range from value that are very low to very high, values of life saved, that kind of thing.

My feeling is that it is inappropriate for the agencies to make those decisions without further direction from Congress. I would like to see Congress give some range or some statement of what it believes a life is worth avoiding or the cost of a life that is worth avoiding. Because right now the agencies are doing it on a daily basis without any guidance from Congress.

Mr. WALGREN. I kind of get the impression that perhaps, except in some specific areas, we tend to take the dodge that it is just a risk, and that is what bothers me about the word risk. I guess in some ways I have a problem with the word risk when you say what you do in an agency is risk management. I would be more comfortable if you were able to say that what you were doing was harm prevention, because the word risk really implies that it may or may not happen, and that is the important question for an individual, but I am not so sure that is the important question—well, wait a minute. The word risk implies that it may or may not happen to a given entity, and that is an important question to the individual. It is a different question if the entity is the aggregate, is the whole of the population.

To say that there is a risk or to use the word risk when in fact we are dealing with a certainty that 0.2 percent of the population will be affected a certain way is the wrong word if you are thinking of the whole. It is the right word if you are thinking of the individual because he may or may not. He or she runs a risk. The population as a whole runs a certainty.

I hope something that we see risk assessment from the agencies that would, if that is the truth, if that is not a fantasized circumstance that makes those distinctions or doesn't lead us to assume that we are dealing with one or the other.

Mr. JORLING. I think what you have hit on is that most of the areas that EPA regulates in and other agencies in the health and environmental business regulate in is because the risk is to the aggregate. That is why we have a justification for public intervention at all. If it were just simply your telling a specific identifiable individual that they run the risk of, that person theoretically can make an individual choice as to whether they want to incur that risk or not.

But these are risks to an aggregate, and that is why public regulation is justified.

Mr. WALGREN. Are they risks to an aggregate or are they certainties to an aggregate, if you use the word risk to mean something that may or may not happen?

Mr. JORLING. They are risks of probabilities. That doesn't help to answer your question, especially trying to take it back to a constituent.

Mr. WALGREN. So, then you go to high probability or low probability.

Mr. JORLING. Yes. Since there are no smokers in the room for the moment, we could use that example. It is certainty that if people smoke at certain rates in a certain size population, some of them are going to get cancer.

Mr. WALGREN. So, that is a certainty. That is not a probability some will get it. It is a fact some will get it. It is only a probability that I may get it or that any individual in the group would get it.

Mr. JORLING. That is right.

Mr. WALGREN. Well, I am sorry for belaboring that. It is sort of a personal interest and I guess I can do it only because there aren't any other members here at the moment. But thank you very much for your basic presentations, that issue aside. I think they are certainly valuable to the discussion. We hope that they will be used as source material for people who will be trying to think about these areas in the longer run.

Thank you very much.

Mr. WALGREN. Our last witness, Dr. Frank Wolek is former Deputy Assistant Secretary for Science and Technology with the U.S. Department of Commerce and who, as I understand it, now is the director of research at Villanova University in the College of Commerce and Finance.

We apologize for being delayed, Dr. Wolek, and appreciate your being able to be here. Why don't you just go ahead and emphasize the points that you would like to, and we will go from there.

STATEMENT OF DR. FRANCIS W. WOLEK, FORMER DEPUTY ASSISTANT SECRETARY FOR SCIENCE AND TECHNOLOGY, U.S. DEPARTMENT OF COMMERCE; AND DIRECTOR OF RESEARCH COLLEGE OF COMMERCE AND FINANCE, VILLANOVA UNIVERSITY, VILLANOVA, PA

Dr. WOLEK. Thank you, Mr. Chairman.

If I can, I would like to ask that the full testimony be accepted for the record.

Mr. WALGREN. It certainly will be.

Dr. WOLEK. I will just briefly summarize. About how much time would you like me to look to?

Mr. WALGREN. Certainly, feel free to take 10 minutes, and a little more if you like if you need it.

Dr. WOLEK. Very good, Mr. Chairman. Thank you.

The core of my paper—or testimony—I am sounding like an academic again—is that agency science is problem-solving science. This not only relates to my own experience in the Government but also particularly to studies that I have done, for example, recently a study of exemplary achievements of a key mission agency. I have found that those exemplary achievements were work on problems.

It could have been opening up new opportunities, but instead it was helping solve problems.

Now, Government can't work on problems without working closely with the private sector, with those that have the problem and those who are also working on it. That means interaction all the way from program definition—which problems you work on, how you define the problems through the research, how you interpret the results, what steps you take and, finally, afterward, how do you extend the results, how do you tie them to other programs. The interaction has to be complete from beginning to end and worked closely.

However, Government cannot work closely with the private sector without strong involvement of public-minded policymakers who make sure that the work is done in the interests of the general public. When you are working closely with industry, one of the problems is you can get co-opted by the private sector. And there are more than enough examples of that. James Hightower's significant book, "Hard Times and Hard Tomatoes," is a very useful example of that type of co-optation.

Policymakers make sure that doesn't happen, make sure that the Government work is appropriate in function and scale relative to private abilities. Policymakers provide the travel programs, the support when the inevitable conflicts are going to arise, the rewards for cooperative achievement, the encouragement for the agency's visibility as a leader and not just a follower of the private sector, and they provide personal accountability to the Congress and, therefore, to the public. That is the basic kind of accountability that you can have.

When these three groups are working together and are balanced around a common agreed-upon agenda, then I find that the agencies make valuable contributions, rely upon in a proper way universities and firms, and that their staffs rise in the quality of output, which is the fundamental quality that we have to be concerned with, to the challenges that have been given to them.

Now, that is an easy statement. It was part of my responsibility and it is part of the other politically-appointed policymakers to a very difficult job of keeping that interaction working. But the core of our concern here is that there be that tripartheid arrangement between the scientists in the mission agencies and Federal laboratories, the policymakers who are politically-appointed and accountable to the public, and their constituencies in terms of the private sector capabilities working on the same problems.

For this balance to hold, you must have, first of all, politically appointed policymakers coordinating mission agency science which is not always the case.

There must be funds and support staffs to promote the interaction and the work of people closely together. That is also not frequently the case and in too many mission agencies, the result is, and I quote from one scientist, "Gee, it is very interesting. Somebody mentioned my work as being exemplary. All I do is publish it and it disappears in the black hole of journals." They don't have the funds. They don't have the encouragement for visibility. They don't have the policy backing when they get into problems with people outside their agencies to encourage them to do that.

There also has to be regular hearings of the type you are having here to provide that personal accountability for results, to assure the interaction, and to assure that there is the impact on the general public.

Finally, I would recommend an OTA study of the major programs where that interaction has occurred to serve as models for other mission agencies.

Now, the desirable state of tripartheid balance that I am talking about, in addition to not always occurring in existing mission agencies, has special problems when the output of mission agency science is information and laboratory services.

When you are coming out with a new chemical or you are coming out with results that imply some changes in technology or current practices in an industry or in the way universities operate, the interaction can occur quite easily. When you are coming out, however, with a compendium of information of what is known about the problem, where it occurs, data bases on current practices, particularly computerized data bases, it is not as easy to interact with people in the private sector.

The reason why it is not is because the capabilities in the private sector are smaller, scattered, and have more limited capital and are more limited in their own research staffs so they don't have the scientific peers with whom to work.

The result is that the mission agencies tend to, in my experience, try to do the job on their own rather than acting as a support and a stimulant to private sector capabilities in the services, that is, consultants, information service companies, and laboratory testing organizations. Output of that type of nature, service-related output, is inextricably wound up into applied science in mission agencies. It is increasingly becoming a part of the output of what they are working on.

The need for tripartheid balance is related to one of the questions in the agenda that you sent me. That is, "What is the role of the mission agencies and the Federal laboratories in the future?" If their current role is problem solving, what will their role be in the future?

Once again, I suggest problem solving, but the problems are changing and changing in important ways. Problems are taking on the following characteristics, for example emergencies, which arise from system dynamics. As our systems get larger and larger, more and more interactions between them and less and less involving of labor on an ongoing basis, small changes can not be seen until they are amplified into emergencies.

This is a simplified example. When you have small grain elevators and people go into them, there is a lot of human labor involved and they sense a lot of dust, the door is opened up and ventilation can be provided. When it is a very large facility and there is no human labor involved, that dust can build up until it takes the form of an explosion.

That is the type of effect that I am talking about, and it occurs in many, many areas: the avian, chicken and turkey, influenza attacks that we have had—catfish farmer where you have one particular breed and a disease that would normally be kept in bounds when you are dealing with small sizes of herds of catfish amplify

when you are dealing with one breed into an entire decimation in a very rapid form of the herds.

A second kind of problem is implementation which requires 100-percent participation, where you can't say, "OK, we have most of the people out there doing what we think should be done, that is all we have to do." That is not acceptable. Everybody has to be involved or nothing occurs, for example, the attack on the boll weevil in the Southern part of the United States. Every farmer had to be involved. Every agent of a local government agency had to follow standardized practices. There had to be cooperation in the acquisition of information and the following of the control practices. That requires education, information monitoring, standardization on a massive scale.

A third type of characteristic of future problems is when the causes stem from accumulative and hidden effects, when you can't just talk about one particular cause that is fairly visible but when it occurs over long periods of time as a result of residues built up in the environment, built up in people, built up in animals, built up in the walls and the floors of the places where we are.

It is very difficult to work on those types of problems, and the importance of interaction between the scientists and the people in the private sector are vastly greater for the three types of problems that I am talking. We set up a huge Federal facility for science. They are very, very talented people, but they are just beginning to interact with private sector capabilities on the scale that these new problems are going to require.

I am sure from what I have seen that they have the talent. I know the public looks to these Federal laboratories and admires them. I now believe they need the support and increased openness to be able to accept and meet these challenges.

Thank you very much.

[The prepared statement of Dr. Wolek follows:]

THE POLITICS OF APPLIED SCIENCE IN MISSION AGENCIES

Francis W. Wolek

Director of Research, College of Commerce and Finance

Villanova University - Villanova, Pennsylvania

Testimony before the U.S. House Committee on Science and Technology

Science Policy Task Force Hearings on

Science in the Mission Agencies and Federal Laboratories

October 24, 1985

One of the highlights of my career has been my association with the mission agencies of the federal government. As Deputy Assistant Secretary for Science and Technology with the U.S. Department of Commerce, I was privileged to work with the outstanding professionals making up the scientific staff of the National Bureau of Standards. After my return to university research on science policy, I was equally honored to do research on some of the world's leading laboratories in the dynamic field of agriculture (The U.S. Department of Agriculture's Agricultural Research Service). I come before you now, because I believe our mission agencies and federal laboratories are in a period of transition which holds both danger as well as promise for American Science Policy.

The Packard Report on the National Laboratories states that this "laboratory complex constitutes an impressive national research and development asset." The heart of the issue before the nation is the definition of the function of this asset. Why is it an asset? Whom does it serve? How does it operate in partnership with other institutions? As this Committee's "*Agenda for a Study of Government Science Policy*" points out, this longer term objective of "achieving a deeper understanding" is basic to the policy issues of organization, accountability and oversight. The theme of my contribution to your deliberations is based on the Biblical maxim that "By your deeds will you be known".

EXEMPLARY ACHIEVEMENTS: PROBLEMS AND THEIR SOLUTIONS

The core of my testimony is based on a study I recently performed of key achievements of laboratories in the Agricultural Research Service (ARS). While the data were specific to ARS, my exposure to other agencies, leads me to believe the findings are generally relevant. The ARS study was based on a sample of 47 achievements in applied science which were a source of pride in the agency and/or the community it serves (i.e., nominated cases came equally from Laboratory Directors and Directors of Research at leading trade associations). My research sought answers to how many of these cases both (1) conformed to principles on the management of applied research

abstracted from academic studies on this subject and (2) had indeed had positive impacts on agriculture practice. This testimony only concerns those 31 cases in which there was an actual and positive impact.

What type of applied science is admired for its practical benefits? You might think the answer is work which opens new opportunities not recognized before creative science uncovered them. You might think it is stunning breakthroughs in exciting disciplines such as genetic engineering. Or you might think it is the output of a brilliant individual cutting through the errors of previous practice. In each case, I was surprised to find that odds were you would be wrong! The applied science admired both within and without ARS was work which helped users (farmers, suppliers, local governments, etc.) *solve a problem* and which was the joint achievement of a *leaders from the worlds of science and practice.*

In short, successful science in mission agencies is problem solving science. Such findings should not be surprising. Experts on the mission agencies such as Henry Lambright who testified before you on October 2nd ("Missions have to do with energy, space, defense, or some other national problem") have emphasized this fact. What was surprising, however, was the magnitude of the finding. I gathered data on 47 different accomplishments, 31 checked out as yielding actual value in practice and 25 of these involved applied science (4 related strictly to technological design and 2 were projects which produced computerized data bases). Of the 25 scientific projects, 24 were directly tied to a problem of some type, usually one which took the form of damaged yields or quality (e.g., weeds choking growth, diseased output, inadequate water supplies, etc,).

Most of the projects involved quite sophisticated science. They were not simple extensions or accumulations of existing knowledge. Furthermore, in almost every case (23 of the 25 projects), a significant change was involved in accepted practice, one that meant change in the skills, staffs and procedures of practitioners. Another distinguishing feature was that government was already an active player on the problem (in five cases local government had the lead role in fighting such problems as insect

control and in another nine cases federal regulatory agencies were significantly involved). This last point bears further stress by referring to the words of Henry Lambright who noted that the mission agencies "are unique in being of the government...They are extensions of government policy" so that their involvement in the problems is a central concern for both wise policy and reasoned understanding of users.

THE POLITICAL PROCESSES OF APPLIED SCIENCE

One of the main points of my testimony is that: the success of the 25 projects stemmed directly from the *political processes* by which they were managed. If I were a social scientist I would not use the term "political". Instead, I would speak about an "integrated social structure", or "participatory networking" or the "joint action of stakeholders". Whatever words you use, the basic issue is politics in the finest sense of the word: getting people with diverse interests and capabilities to work together for common ends.

Now let's be more specific about how science is used to serve the needs of its users. In doing this, I need to refer to three principles which emerge from academic studies. Briefly stated, this literature argues that the results of scientific projects will only produce change if: (1) projects are mutually defined by scientists and the users who must implement the changes (i.e., those with the problem), (2) users directly interact with and share in the decision making during the research (i.e., people work together on-site to understand needs and operating conditions) and (3) the findings are aggressively disseminated through networks of opinion leaders in the user community (i.e., recognized people put their reputations and money on the line). My study found that there was still a significant chance of success if only two of the three principles were followed, but that is quibbling (in the 13 cases where none of the principles held, only 3 had a valuable impact). The basic point remains: government scientists must work directly with users if applied science is to have an impact.

Figure 1 summarizes the point by noting that: there will always be some type of relationship (active interaction, passive disregard, open opposition, etc.) between the three

groups involved in applied science -- Scientists, Users and Policymakers. If an agency tries emphasizing any one without reaching a balanced understanding with the other two you will find mission distortion, waste and conflict. Science without policy and problems leads to scientists competing with universities to produce papers for abstract journals. Dominance by policy leads to another condition familiar to our national labs: scientists giving lip service to an administrator while bootleging projects they and users want. Nor is the condition of user dominance any better, for the past has shown that it can lead the mission agencies to become firefighters on second-rate projects with negative side effects for the general public (re. Hard Times and Hard Tomatoes by Hightower).

To be sure, scientists will argue the importance of scientific freedom just as users will argue the pre-eminence of taxpayer control and policymakers the importance of vision and political mandate. The public is fortunate in having Congressional forums in which no one group is dominant and they jointly assure the public that they are facing their political mission of working together. For when they do, you may be confident that their strengths will emerge and the long-term public interest will be served.

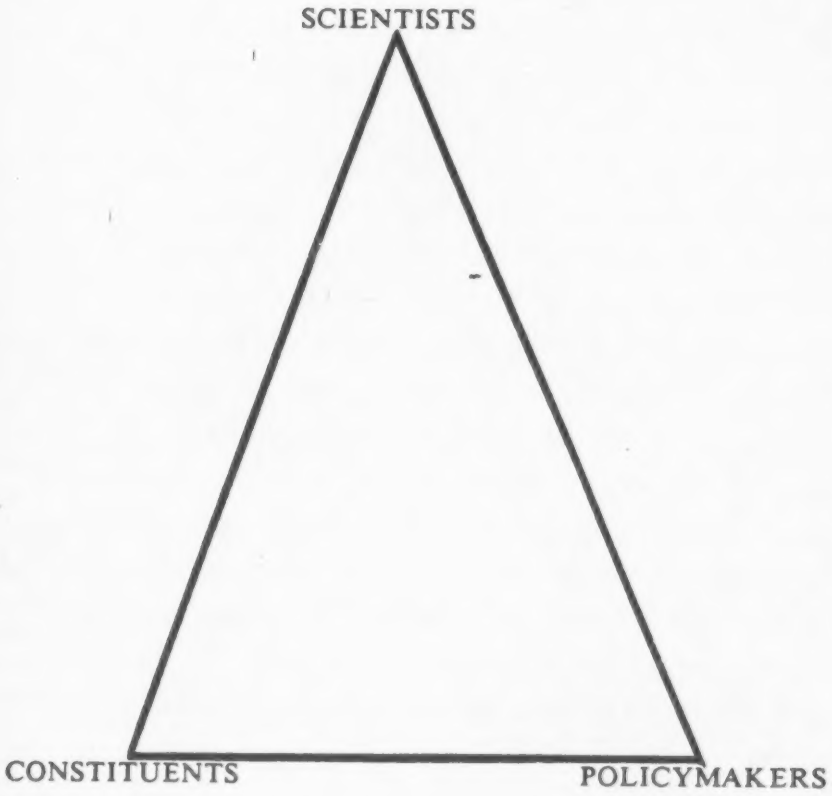
DISFUNCTIONALLY LIMITED CONSTITUENCIES-

Before discussing the implications of the above perspective, it will be useful to describe another characteristic of the exemplary projects in my studied. That is, Figure 2 describes 27 of the 31 projects according to the nature of the contribution to users who have the problem: (1) a new agent (e.g., a herbicide) which promises increased effectiveness, (2) a new test method (e.g., test for toxins in grain) which promises better diagnosis and monitoring of effectiveness and (3) new information (e.g.,a compendium of on the occurrence and control of a farm animal disease) to guide users in avoiding or controlling the problem.

Recall that a critical factor in the success of applied science is strong interaction with an active constituency from the start of a project through its early implementation. When new agents (insecticides, vaccines, plant varieties, etc.) are the outcome, the nature of the constituencies is clear: both producers who are experiencing the losses and

Figure 1

THE SUPPORT STRUCTURE OF FEDERAL LABORATORIES



industrial suppliers who market such agents (chemical firms, drug companies, hybrid seed producers, etc.). What is also clear is the process of interaction: working through a farm organization to produce grass-roots participation and with peers in R&D at the suppliers.

The situation is quite different with the other kinds of contribution: consultants and testing organizations are loosely organized, widely scattered and lacking in the R&D staffs permitting peer relationships. In short, current practice works well when the output of applied science promises a new or better product. When the output promises a new or better service, the system often breaks down.

Working with consultants, testing labs and information companies is indeed more difficult and less rewarding (e.g., because they are small, the same message has to be repeated many times, because they are more narrowly focused the message must be adapted to be heard, because they lack discretionary capital they resist staff and equipment innovations, etc). However, as long as mission agencies produce service-enhancing results (and these are inextricably involved in the problems of users) and as long as the Congress and the Office of Management and Budget will not accept mission agencies becoming commercial service operations (which would be wasteful competition with growing, private sector capabilities), we have no choice but to find ways to aid and encourage the mission agencies to work with private-sector service firms.

My message is simple: the problems of users are driving mission agency professionals into a corner. They can't help but generate service enhancing results, but they lack the internal and external support for the more difficult tasks of working with service firms. Therefore, they either publish the results and fret that no one responds or they offer limited services themselves ("we'll just do it this once to show it can be done", or "we will only help our local friends", or "we'll start our own "extension" service") and fret about inadequate budgets and misdirected talents.

A Congressional Hearing on the *Mission Agencies and the Service Sector* would serve a national need by bringing this growing problem to the attention of all concerned and yielding such practical benefits as:

- o defining the criteria for determining when mission agencies are in unwarranted competition with private organizations and when they stimulate that sector's growth;
- o highlighting the function of specialized training, field days, private sabbaticals and other ways of generating interaction between private experts in the services and government scientists;
- o providing a stimulus for private services to become better organized for working with mission agencies,
- o pin-pointing specific situations where public resources could be saved by terminating duplicate services between private and government organizations,
- o sharing lessons between agencies on successes such as the Patent Office's sale of its full-text data-base and the Environmental Protection Agencies conferences for computer firms on water-management models).

REPLIES TO INQUIRIES IN THE AGENDA REPORT

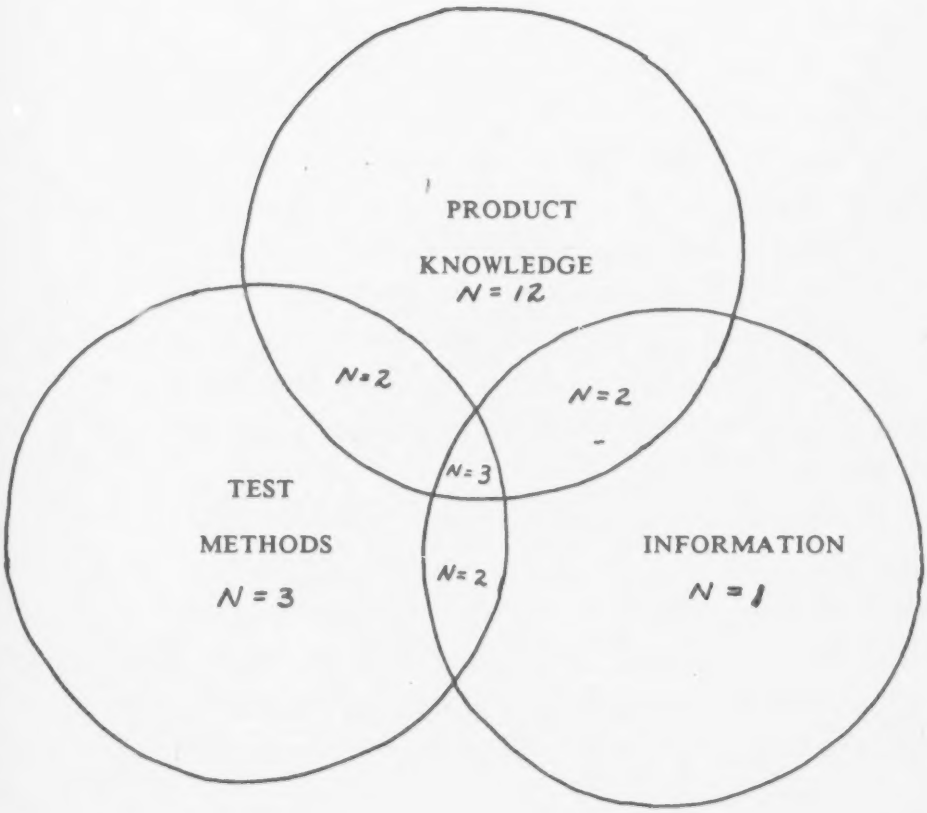
The Committee has been generous to its witnesses in providing the "*Agenda for a Study of Government Science Policy*" with its specific lists of questions to which you wish answers. Therefore, I will restrict my discussions of the implications of my remarks to those issues.

What are the Present and Future Roles of the Large Number of Government Laboratories?

The data obtained are consistent with the testimony of other experts on the role of federal laboratories and mission agencies: they are the base of scientific expertise for contributions to the solution of problems of wide concern in society and in which public policy plays a role. The specific contributions of the laboratories are :

Figure 2

THE CONTRIBUTIONS OF FEDERAL LABORATORIES



- o knowledge which defines the potential of and/or improvements in practices and technologies which would alleviate the problem,
- o information services which instruct users about the extent of the problem and actions they may take to minimize it, and
- o technical services which assist private sector organizations to better understand the problem.

The laboratories have an excellent record as producers of useful knowledge when there is time for published information to be useful and where there is a consensus that government possesses unique capabilities. Such work will undoubtedly continue to be of importance as new problems emerge. However, as other witnesses in these hearings have suggested, both of these conditions are increasingly less likely to hold. In particular, the laboratories and their mission agencies will need to adjust to needs for direct interactions with increasingly strong and diverse talents in universities and private organizations. To combat this situation, the mission agencies will have to greatly increase their capacities for working in cooperation with other scientific groups and with the networks of suppliers, practitioners and associations (e.g., enhanced travel budgets, readiness of policymakers to handle conflicts, recruitment and promotion practices which recognizes cooperative accomplishment, increased ways of being visible as a catalyst of scientific consensus, openness to project re-orientation based on outside consensus, etc.).

My studies also suggest that the mission agencies have had special problems making information and service contributions in ways which recognize the capacities of information companies, technical service laboratories and consultants. While there is sufficient reason to strengthen these abilities in terms of today's challenges, the need is even greater for the problems which mission agencies will face in the future. For example:

- o *Problems Traceable to System Dynamics* - as our systems become larger, more and more tightly inter-related and less dependent on human labor, errors in one element of the system can be multiplied into suddenly appearing emergencies (e.g., grain elevator explosions, chicken influenza epidemics, catfish farming disease catastrophes);
- o *Requirements for 100% Participation* - there are many problems where the solution is dependent on all practitioners following a prescribed course of action, therefore, education, testing, consulting and monitoring services are crucial (e.g., where exports of cherries to Japan depend on all packers conforming to insect control practices, where the elimination of the boll weevil requires 100% coverage of farms and coordinated practices across all local agencies, where control of disease requires 100% testing of flocks and 100% destruction of exposed animals); and
- o *Problems Traceable to Accumulative, Hidden Effects* - increasing sophistication in health and environmental sciences shows that many problems arise not from any one cause, but from slow and often hidden accumulations of the interactions of multiple factors and the result is a need for sophisticated testing, on-line data-bases and education on seemingly innocuous practices (e.g., waste handling, long-term effects of farm chemicals, interactions of nutrition and environment on human health).

What Should Be the Policy with Respect to the Establishment of New National Laboratories and the Reorientation of Existing Facilities?

There are three indispensable groups which are needed for a productive contribution by federal laboratories: scientists, policymakers and (most important) users. This structure gives rise to the following rules regarding the establishment, termination and reorientation of laboratories:

- o If the actions of all three groups fail to support the lab, do not establish a new lab or terminate an existing one with appropriate policies on relocation and adjustment of the staff.
- o If the actions of any two groups fail to support the lab, a new one should not be established (i.e., science or policy should not "push" a productive lab into life) and an existing one should be placed on short-term trial with the specific mission of reorienting to obtain the needed support without loosing the existing.
- o If the actions of two groups show balanced support, but the action of any one group fails to support the lab, and if
  - the missing group is the most critical one of private sector users, the lab needs reorientation on the problems which it is addressing and its programs for cooperating with the private sector;
  - the missing group is that of policymakers and the Congress believes the lab is serving a vital function, the Congress should call on the Executive for accountability and/or serve as interim policy support;
  - the missing group is the scientific staff (i.e., it has lost vitality or currency), the lab may be reoriented via the introduction of a critical mass of new scientists.

The primary means which may be used to assess the health of each group's support and to structure the reorientation when needed are:

- o *Constituents* - Advisors convened in "Strategic Conferences" which meet every 3-5 years to define program directions and cooperative goals.
- o *Policymakers* - Congressional Hearings centered on politically appointed policymakers who are personally accountable for mission agency effectiveness and impact on the general public.
- o *Scientists* - National Academy and other scientific advisory groups.

How are Decisions Made with Respect to the Science Programs to be Done in the Government's Own Laboratories versus Their Conduct Through Grants and Contracts?

It is commonplace to note that there is no simple answer other than it depends on the circumstances. Figure 3 presents a framework which provides a useful perspective on these differing circumstances. In each of these situations, private sector research groups interact in some way with the same parties as mission agencies. When the interaction is only between scientific peers, the basis for allocation between agency and private laboratories will be peer evaluations of scientific interests and capabilities (judged by publication record, laboratory capabilities, theoretical focus of work, adequacy of methodology, etc.). The second situation occurs when government and private groups do not directly interact, but both have related contacts with practitioners. In this situation, the judgment, temporal needs and practical exigencies of the practitioners will have much to do with how funds are allocated. When no interactions with common communities is present, administrators must make allocations based on their understanding of political pressures from their own labs, Congress and constituent lobbies. Obviously, it is best to avoid this third case, and the best situation is described by the fourth where there is a consensus including both outside peers and practitioners.

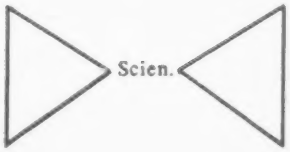
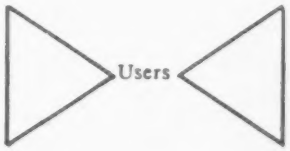
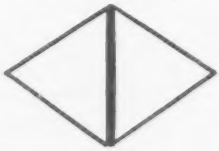
What is the Record of the National Laboratories in Attracting and Retaining Highly Qualified Research Personnel?

My reply to this important issue is: whenever the users of an agency actively interact with its policymakers and share a consensus on the mission and agenda of the agency, then the scientists will rise to the challenges implied in that consensus! In other words, I have great respect for the scientists I have worked with and studied at mission agencies. They may not all have Ph.D.'s from our elite universities, but given an important and valid challenge, they perform.

This upbeat note which reflects my deep respect and admiration for the dedication and competence of the mission agencies is an appropriate end to my testimony. Thank you for the honor of appearing here.

Figure 3

STRUCTURES DOMINATING RESOURCE ALLOCATION

NAME	DIAGRAM	ALLOCATION RULES
Scientific Judgement		Peer Evaluations, Theory
Practitioner Power		Lobbying, Economic/Time Factors
Administrative Control		Quotas, Directives, Turfguards
Strategic Consensus		Strategic Agendas for Shared Work

Technology In Society, Vol. 7, pp. 11–23 (1985)
Printed in the USA. All rights reserved.

0160-791X/85 $3.00 + .00
Copyright © 1985 Pergamon Press Ltd

Guayule

A Case Study in Civilian Technology

Francis W. Wolek

ABSTRACT. This case study documents the difficulty of initiating civilian technology programs in government. Earlier work has focused on the political actions of supporting and opposing constituencies. This paper deals with institutional factors in the process of resource allocation, which are designed to create obstacles to the initiation of new programs. The paper also outlines managerial tactics available to government executives, which may mitigate the obstacles when coupled with responsible analysis of public needs and values. It concludes that civilian technology programs are difficult but feasible undertakings and that, despite their scanty record of success, they can be deserving of public resources and support.

The public's confidence that modern technology is a cornucopia of jobs and economic progress has motivated politicians to support programs promising enhanced innovation, those of the so-called Atari Democrats being only the latest in a long line of clarion calls to participate in the bright tomorrow of a technological society. These initiatives have won important support—transcending the Manichean world of politics—from academics who share the public's confidence in technological progress and who also wish to enhance the contributions of universities to society. No less than a Nobel Prize-winning economist has provided the theory needed to argue an indispensable role for government. Briefly, Kenneth Arrow argues that private aversion to risk and inability to appropriate the full benefits from innovation will lead industry to underinvest in long-term, far-reaching R&D.

Given the political power of public confidence and support of leading people, the concept of civilian technology has been accepted by most modern administrations of the US Government (*e.g.*, the Civilian Industrial Technology Program of President Kennedy; the National Technological Opportunities Program of President Nixon; and the Innovation Initiative of President Carter). Despite the attractiveness of the concept, and despite the strong support of Republicans and Democrats, the record of accomplishment for civilian technology programs is modest at best (see Katz for a fine review of the history of major programs).

Francis W. Wolek, currently at the College of Commerce and Finance of Villanova University, has spent most of his career in academic research on science and technology policy. He has also had the opportunity to implement his own and others' scholarship as Deputy Assistant Secretary for Science and Technology at the US Department of Commerce and as Vice-Chairman of the US Guayule Commission.

The coupling of great promise with apparent failure has attracted the attention of all concerned: scholars (*e.g.*, Magill and Rogers), government officials (*e.g.*, Schlie), and industrialists (*e.g.*, Baer *et al.*), alike. The conclusions of much of this previous work appear to be that either civilian technology is an improper goal of government (*e.g.*, the work of Eads and many industrialists) or that executives of superordinate talent in politics as well as technology are needed for success (*e.g.*, the work of Nelkin). In each case, the message of policy analysts is a negative one, discouraging further efforts to create and/or manage civilian technology programs.

It can be assumed that technology will continue to be a major focus for public confidence (*i.e.*, civilian technology programs will continue to be a favorite of politicians) and that the government officials placed in charge of these programs will possess quite ordinary talents. In short, the dangers of future failure are high. To combat these dangers, the author will offer several lessons learned by a student of technology policy who was privileged to apply his—quite ordinary—skills to the management of a civilian technology program to create a domestic, natural-rubber industry.

Perspectives on Government Programs

The lessons offered here stem from an "institutional" perspective which views the management of government programs as a process of simultaneously addressing the requirements of interest groups outside government, bureaucratic procedure, and executive policy. In adopting this perspective, this discussion is closer to the work of such scholars as Cyert and March than to the perspective of the social/political school, such as Nelkin (the political perspective) or to the work of economists of technology policy, such as Nelson, Peck and Kalachek (the rational perspective).

According to the political perspective, the success of government programs is largely a function of the political power of friends and enemies. Key questions concern the strength and skill of supporting officials and the influence of external constituencies. From this perspective, a successful program would be one which was supported by the President and Congress, and managed by officials who understood political power and made sure it met the needs of an active constituency.

The rational perspective places its emphasis upon the justification of a program. Key questions concern economic returns to society and to those in industry who will be needed to commercialize the technology. A further question, especially targeted to government programs, is why private groups, acting on their own, cannot obtain the returns indicated (*i.e.*, why is the government needed at all?). From this perspective, a successful program would be one which provided high value to both the public and industrial producers who would otherwise have to settle for less.

The political and rational views have dominated most of the literature on civilian technology programs. From these perspectives, the failure of the programs must be traced to errors in either the design of the programs or in the use of power in managing them. These are valuable lessons; however, it appears that they oversimplify the requirements for program success. For example, important, recent work (*e.g.*, Bodde) has stressed the need to understand the decision processes of government, and to integrate political and rational analyses of programs. Political power and

economic return are necessary, but they alone are insufficient for the success of civilian technology programs.

An additional perspective is necessary, one concerned with the internal workings of the government itself, *i.e.*, the institutional perspective. The key questions seen from this perspective are: the support of interest groups in the government, ability to meet bureaucracy on its terms, and skill in maneuvering around policies which can facilitate or retard a program. From the standpoint of this perspective, the successful program will be one which fits the interests of multiple parties in government, has the enthusiastic support of people who understand government procedure, and is positioned to fit the formal policies of executive agencies.

The Program

Rationale and Program Description

Guayule is the common name for a bush (Parthenium argentatum) which grows naturally in the deserts of the southwestern United States and northern Mexico. Public interest in guayule is based on its production of high-quality latex, similar to that produced by Hevea trees growing in Malaysia and South America. Natural rubber is important to public policy, because it has significant military uses (*e.g.*, tank treads), and because the United States is militarily dependent upon imported rubber. Additional public benefits concern guayule's potential contribution to the economic development of arid areas.

The guayule program was brought into existence on November 4, 1978, by the Native Latex Commercialization and Development Act (P.L. 95-592), which authorized $30 million for R&D and commercialization over a three-year period. The result envisioned was a vigorous industry which would grow guayule bush and process the latex into high-quality, natural rubber. P.L. 95-592 also established a United States Guayule Commission made up of representatives from the Departments of Agriculture and Commerce (three members from each), and the Department of the Interior and the National Science Foundation.

History

Guayule production was supported by the US Government in the 1940s when the Japanese takeover of rubber plantations in Malaysia highlighted the strategic significance of natural rubber. The needed seeds for some 5,000 acres of guayule in the southwestern states were obtained from uncontrolled collections of wild bush in Mexico.

Confirming the cynicism of those who believe that government is fickle, the program ended with the war, and the guayule was burned as it stood in the fields. This abrupt termination—which left no time for records of the scientific work—and its lesson of the temporality of political support would continue to haunt supporters of the modern program.

The plight of the semi-arid lands of the Southwest in the 1970s (rapidly declining water tables, economic hardship for farmers of irrigated land, and threatening

dust-bowl conditions) generated renewed interest in a guayule industry. Predictably, interest led to the formation of a "blue ribbon" study group, and a National Academy of Science panel examined the scientific, technological and economic feasibility of developing a native latex industry in the United States. The findings of this study were that an industry was feasible, but that it would require substantial effort in: (1) plant breeding for higher rubber content; (2) development of successful agronomic methods; (3) development of profitable processing technologies; and (4) support for an agricultural and industrial infrastructure.

Congress, however, would not tolerate a long (15-to-25-year) plant breeding program; they saw the program as ready for active promotion. Therefore, Congress divided responsibility for guayule development between the Departments of Agriculture and Commerce. The Agriculture Department would be responsible for accelerated research on plant breeding, and also the development of agronomic practices, while the Commerce Department would be responsible for research on processing technology. Both departments would share responsibility for the development of an industrial infrastructure of farmers and processors.

Political Context

There was important support for the Guayule Program from farm groups in the southwestern states, based upon the prospect of establishing a new cash crop. The need was based on declining water tables resulting from heavy irrigation of the most widely produced crop: cotton. If forecasts of further declines proved true, farmers would be forced out of cotton production, and either into a new crop or out of business. This resulted in Congressional interest in and pressure behind the program. Since the threat was in the future and there were no existing guayule farmers, however, there was no strong constituency behind the program. In this regard, the guayule program is an excellent prototype of most civilian technology programs.

It is important to note that there was also clear interest on the part of some farsighted rubber companies, who perceived a day when they might need alternate supplies of latex. Goodyear and Firestone were especially active, and the latter maintained a small guayule plantation. Finally, it should be noted that, for several years prior to the Native Latex Act, the National Science Foundation (NSF) supported academic research on guayule. The result of NSF's work was a significant group of university scientists experienced in and committed to native latex research.

Institutional Obstacles to New Programs

One of the most basic tasks facing all supporters of a civilian technology program is to obtain the necessary funding. To the public, commerce and industry, the amount of resources expended on a program is a fundamental measure of both the commitment of the government and of its success in backing that commitment with action.

The Native Latex Act of 1978 authorized the expenditure of $30 million in federal funds for a period of three years. In response, groups in the Southwest (mostly universities and potential farmers) turned to the Commerce and Agriculture Departments for funding. Actually, over the first three years of the program, the Agri-

culture Department provided approximately $3 million in funds, and the Commerce Department provided approximately $200,000. The contrast between expectations and actual funds was frustrating to political supporters and to advocates hoping to enter the natural rubber business.

Authorization vs. Appropriation

Most people outside government believe that, when the Congress passes an act which authorizes funds, these funds are immediately available for use. This simple view of government funding is simply invalid.

Funds must be "appropriated" to match an authorization, and program staffs must be recruited and organized. Appropriation is a different process from passing authorizing legislation, and generally requires that the Executive Branch request funds and that these be approved by departmentally organized Appropriation Committees in Congress. Since the Guayule Act was not initiated by executive agencies, and was not expected, no prior work had been done which would lead to the early availability of funds. The earliest that funds could possibly be available would be October 1979, if the Commission could include Guayule in the 1980 budget.

The Dynamics of the Budget Cycle

When the act was unexpectedly passed in 1978, the agencies involved had completed preparation of their 1980 budgets (Fiscal Year 1979 had started in October 1978). Budget requests, not including Guayule funds, had already been developed and processed by the Office of Management and Budget (OMB). The "budget window" had closed, and funds for Guayule had to wait for the 1981 requests. The importance of timing in the "budget cycle" is generally not understood by the public, but is a fact of life in the bureaucracies that are as much its victim as its master.

By the time the Guayule Commission had met and approved a clear strategy, six months later, the 1981 budgets were well on the way to development. There were programs, however, already in the 1981 budget which were in existence prior to the Native Latex Act. Therefore, the Guayule Program had to compete with an already structured budget, backed by prior commitments.

Agency budgets are not open-ended, and—for almost all intents and purposes—are best thought of as fixed. In other words, the budget process is a zero-sum game, and new programs are only possible if existing ones are cut. Needless to say, it is always difficult for a new program to cut into an established budget, either in terms of a large request or a high priority. Indeed, it was not until the 1982 Budget request (which won OMB approval in the fall of 1980) that significant new funds would appear in the President's Budget.

Program Authority and the Lead Agency Issue

One of the more important policies which guide the budget process is that an agency cannot receive appropriations unless it has both the legislative authority and OMB (*i.e.*, White House) approval to commit such appropriations. Authorities to

make grants, guarantee loans, support market prices, and enter into construction contracts are not possessed by all agencies. If the agency charged with managing a civilian technology program lacks the needed authority, it must either obtain it—a time-consuming and politically sensitive process—or it must convince a sister agency, facing its own priorities and political pressures, to cooperate in the program.

The function of program authority in the budget process should be clear. By limiting the number of agencies with authority to make specific types of resource commitments, budget officials simplify the budget process and make sure that resources are concentrated in agencies with the needed mandate and expertise.

The issue of program authority is raised to an even higher level of importance by the "Lead Agency" policy of OMB. According to this policy, a specific agency of government is designated as the only one which may commit resources directed toward a specific mission of the government. For example, the Environmental Protection Agency is the lead agency on funds for research on environmental pollution. All other programs needing resources for pollution research face the difficult task of convincing EPA to replace its own requests with theirs.

The Agriculture Department was successful in including funds for Guayule in its budget for agricultural research, since the USDA was already the lead agency in charge of that mission. An added helpful feature was that guayule research would require a small budget relative to USDA's total program for research at state land-grant universities. Therefore, substantial shifts in the agricultural research program were not necessary to accommodate Guayule proposals.

The Commerce agency in charge of the Guayule Program was operating without an established program for making research grants, and faced the difficulty of winning new program authority. Needless to say, the whole concept and function of the lead agency policy would be a sham if it were granted easily and for such narrowly specific missions as native-latex industrial development.

In summary, OMB argued that, if the Guayule Program were important, it should rank high in efforts to utilize existing funds rather than make a claim on new funds. The difficulty with this argument was that there was an already established constituency defending the existing pattern of funding.

The Necessity of Avoiding Reprogramming

Obviously program funds are more easily obtained if the agencies involved are the lead agencies for the needed tasks. The question arises as to why the Commerce representative on the Guayule Program was not from an agency with relevant authority.

There are two answers to this question of representation, and each of them has important implications for civilian technology programs. The first concerns the fact that there was a Commerce agency with lead agency authority to make large grants in the interests of regional economic development, *i.e.*, the Economic Development Administration (EDA). Once the Native Latex Bill was made law, however, EDA officials carefully avoided involvement with the program. They took such action to avoid pressure to "reprogram" (to substitute new projects and priorities for existing ones). EDA's program was a complex result of lobbying from powerful

groups which had long experience with the agency (*e.g.*, state and local government, industrial associations, and unions). If an official could avoid trading off one group or Congressman against another by sidestepping membership on a new "Commission," it was certainly worth it.

Another agency, one which supported research on industrial technologies, was the National Bureau of Standards (NBS). Again, if Guayule officials had ordered a program of research at NBS, and they had the formal authority to do so, existing programs (which those same officials had fought hard to defend) would have to be cut. In short, the necessary informal authority did not exist. Indeed, it was not surprising that NBS scientists, fearful that the formal authority might be used, resorted to the career official's arsenal of procedural, scientific and political steps to avoid reprogramming (see Heclo for further, fascinating details).

Barriers to Multidimensional Authority

The second factor affecting the use of lead agency authority concerns the type of authority available versus the type needed to carry out the mission. The Guayule Program involved a combination of R&D and industrial planning, while agencies tend to have very specific authorities.

Problems of matching civilian technology needs and program authority/experience will undoubtedly continue to plague such programs. It is their special nature to combine significant advances in technological state-of-the-art and infrastructure development. Such combinations of program authority and expertise are rare. The problem can be dealt with by creative work between existing agencies. This, however, takes considerable time, commitment, and the good will of other agencies.

Presidential and OMB Priorities

In the case of Guayule Program, the author (as Vice Chairman of the Commission) made matters worse. The President had made a speech, and negotiated a treaty with Mexico which gave support to cooperation on desert plants, including Guayule. It seemed that, if the Guayule Program could be included in the Department of Commerce request to OMB, its priority did not matter. In other words, it seemed that Presidential interest would overcome the usual need to compete with established interests.

Nothing could have been as wrong and as naive as the assumption that OMB would automatically support a Presidentially backed treaty. In fact, the President's speech and the treaty had little influence on the budget process. Presidential commitments have validity, to be sure, but are a political expression responding to domestic and international forces. Program officials still hold responsibility for guiding budget requests past the necessary challenges of Departmental, OMB and Congressional watchdogs.

Summary

New programs come into existence as a result of lobbying by individuals with the vision and self-interest to define them. The nature of Congressional processes in

the US, (typified by officials who must be sensitive to local interests, relatively short leadtimes, and specific points in time when pressure will be effective) make it possible to pass enabling laws which authorize funds. Lobbying groups, however, must begin again, if they are to translate success in authorization into the reality of program funds and staff. This second process, often not understood and appreciated, is centered on the Office of Management and Budget and the Congressional Appropriation Committees. It is a far more difficult and time-consuming process.

The Office of Management and Budget is an effective watchdog for public funds. OMB has an extensive arsenal to protect the public against untimely or purely political programs. This arsenal includes: (1) policies (*e.g.*, the lead agency policy); (2) procedures (*e.g.*, the inter-program competition for priorities needed in zero-base budgeting); (3) bureaucracy (*e.g.*, the long lead-time involved in budget preparation and approval); and (4) informal means (*e.g.*, career executive defense of the *status quo*).

Civilian technology programs find the above obstacles especially imposing, because the programs are: (1) new in concept; (2) lacking in large, established constituencies (by definition, they are in areas in which private groups have not acted); (3) dependent upon politically appointed and bureaucratically inexperienced officials; and (4) difficult to document with data on cost effectiveness (by definition, the technology has not yet been developed).

In short, from the standpoint of theory, civilian technology programs are promising and exciting. The Guayule Program shows that they are also feasible. This feasibility, however, is only possible given time, persistence and luck!

The Role of Program Management

All of the above (budget-cycle timing, lack of lead agency authority, and reprogramming avoidance) are aspects of the institutional structure of the federal government, which lengthens the time and increases the political strength required for civilian technology programs to be established. In terms of the overall public good in avoiding proliferation of weak programs, this situation is undoubtedly to the good. For those committed to civilian technology programs, however, it is very frustrating!

Fortunately, there are options open to officials who are willing to accept the institutional structure and experienced enough to recognize the considerable stock of managerial tools available to them. The managerial approach will probably never deliver the funding and the scope of activity needed for full-scale implementation. However, this approach will preserve program momentum, and succeed in making basic contributions of data and network organization.

The four elements of this managerial approach, which played a strong role in the Guayule Program, are:

- Officials of agencies with appropriate program authority were cajolled into using their funding to support the Guayule Program;
- Interim funds were begged and borrowed to maintain program momentum and provide basic knowledge for future planning;

- New program authorities were piggybacked on more politically attractive programs; and
- The program was redesigned to fit available funding.

The Politics of Mission Identification

In attempting to win the support of officials in government, much depends upon whether the new program is seen as compatible with an agency's mission and supportive of its stature with the public. The top officials of the US government are politically appointed and, therefore, always attentive to public favor.

When the Guayule Program was originally conceived, it was identified as a program for the "Utilization of Arid Resources." This identification was neatly related to the public interest in resource conservation. By the time the act was passed, however, the concept of conserving the earth's resources was no longer politically significant. Equally important, the mission of conserving arid resources had only narrow relevance (*i.e.*, agricultural research) to the two departments which were to play primary roles in the program.

A mission which was both more relevant to the bureaucracy and more politically meaningful was the concept of "Rural Development." This concept of economic development for rural areas was especially important in justifying a wider scope for USDA's support than that of agricultural research. If the Guayule Program had been successful technologically, there would have been a need to provide loans and subsidies to farmers who would experience no cash sales until their plants matured. Such funding was only available for the mission of regional economic development.

The definition of mission for the Guayule Program was not static, and had to change repeatedly to keep pace with a dynamic political climate. For example, later in the program's history, it became prudent to emphasize the program's ties to "National Security." The United States had a minimal stockpile of natural rubber available, and the Defense Department had listed natural rubber as one of its top three materials in short supply. This concept of critical materials was very important in efforts to justify funding via the Defense Preparedness Act implemented by the Office of Emergency Preparedness.

In summary, civilian technology officials must be attuned to politically viable concepts in their dealings with the public and other officials. In addition, program missions are important in winning the personal commitment of officials in charge. If a program does not support the overall philosophy and personal ties that motivate a key official, it will get nowhere.

Extra-Budgetary Hustle

The officials on the Guayule Commission found that, if they were to obtain any funds for the Guayule Program (before the hoped-for 1981 Budget), it was necessary to find sources of interim funds that were both appropriated and uncommitted. The task was to convince the officials in charge that guayule was a valuable and relevant way to use their funds.

The Commerce Department was successful in obtaining a decision to allocate

$100,000 from the Secretary's discretionary fund. The funds were used for a study on the by-products (resins, waxes, etc.) produced in guayule processing. This research was important, because the economics of guayule processing could depend upon the value of the by-products obtained. Neither the market values or the costs and difficulties of obtaining these by-products was adequately understood.

In the Agriculture Department, extra-budgetary hustle was successful in generating $500,000 from the Energy Department (DOE) by using personal friendships and the argument that natural rubber would conserve petroleum used in producing synthetic rubber. These funds played a role in the efforts of Agriculture to obtain a sufficient supply of seed of the highest yielding varieties. Without adequate seed, it would be impossible to plant the large plots needed to test and to develop agronomic practices.

Piggybacking Program Authority

As noted above, there was no chance that Commerce could establish program authority for as small and as politically weak a program as Guayule. The Guayule Program, however, could be packaged as one application of the broader mission of industry-government cooperation in technology, and this concept did have broad public support, particularly on the issue of technological competition with Japan. In addition, there were other "orphaned" technology programs which lacked sufficient authority and political power. Finally, Commerce's Guayule officials were no longer "greenhorns" with little informal authority. For example, when it came time to provide a critical priority for Guayule in the Department's budget, the Assistant Secretary in charge told the Vice Chairman: "You've given your all to support our projects; now it's your turn." In short, the time was ripe to piggyback the Guayule Program onto the general mission of civilian technology.

The result of this piggyback approach to program funding was a successful request in President Carter's 1982 budget (scheduled for initial expenditures in October 1981). The Guayule Program was made part of a new Resource Technology Program, made up of the Guayule Program and a Resource Recovery Program. The Resource Recovery Program (waste recycling technology) was also a product of legislation to promote civilian technology, and had run into exactly the same difficulties of lead agency authority and competition with established programs. Thus, two resource technology interests shared a piggyback position on an election-year issue of supply-side, innovation-oriented, industrial policy (President Carter's Innovation Initiative, which led to the National Innovation Act of 1980).

Program Redesign: The Chicken or the Egg Problem

One of the key tools of program managers is that of program design, since they are the ones who ultimately determine what will be done, and when, and by whom. One way in which this power may be used is to redesign program tasks and priorities to fit available funding. During the early stages of a program, redesign is difficult. Officials are heavily involved in the budgetary process, are learning the ropes and the program, and have no staffs to help until funds are appropriated. The result is that plans and budgets are all too easily formulated with incomplete understanding.

The key place where redesign played a part in the Guayule Program was, not surprisingly, the most expensive task of all: the funding of a factory to process guayule bush into latex. The need for government support in this area (entrusted by the law to the Commerce Department) is related to the fact that Guayule latex is entrapped in the cells of the bush and must be extracted by grinding. An added complication is that, once the bush is harvested, reactions take place which chemically link the latex with resins and other compounds in the cell walls. Separation processes for the resinated latex are highly uncertain, and were expected to require much in the way of initial R&D and pilot plant experimentation.

Before privately financed factories could reasonably be expected to be built, a pilot plant was needed to develop and demonstrate an economically feasible technology. The problem was that the economic operation of a pilot plant required high levels of capacity utilization. Thus we have a classic problem: The bush would only be grown if a pilot plant were available, and the pilot plant would only be available if sufficient bush were grown.

The Commission was handed a clear strategy for the processing problem when it came into existence. The enabling legislation for the program took the easiest approach to government support: Spend the problem away. The Commerce Department was to subsidize the design and construction of a pilot plant. The pilot plant would then enter operation until the economic feasibility of guayule had been proved, and industry would have the knowledge and incentive for full-scale commercialization.

A small problem with the subsidy strategy was that it was impossible to obtain the funds.

The Defense Department, impatient for the development of a domestic rubber industry, argued that it would be possible to stimulate private industry to fund the pilot plant. To accomplish this, the government should provide a guaranteed price —not only to farmers for bush, but also to processors for rubber. The government would purchase the rubber at the subsidized price until the venture became commercially feasible on its own, at which time the government price would be set at market rates.

The critical assumption underlying the price stimulation strategy was that the price could be set at a reasonable level. The Guayule Commission strongly felt that a reasonable price was not likely, because it would have to be adjusted for the high risks involved. The risks associated with pilot plant operation, and particularly with sufficient bush being grown within a reasonable length of time were so great that the Commission and the industry believed that the price level would have to be unreasonably high. The Commission was also concerned that the price support and subsidization strategies could: (1) encourage unscrupulous operators more interested in large subsidies than commercial ventures; and (2) require a new bureaucracy to administer the program.

As experience grew, new approaches which promised reduced funding requirements came to light. Processing uncertainties centered on the critical step of deresination: separating the by-product resins from the latex. If the bush could be locally crushed and the latex extracted in unresinated form, reliable and inexpensive technologies could be used. Indeed, it would be feasible to set a price on the unresinated rubber, given the low uncertainties and costs of a crushing/extraction operation.

The key question in this strategy is the utilization of unresinated rubber. The problem is that the longer the resins stay in contact with the latex molecule, the more they become chemically attached to it. If the unresinated rubber could be shipped within a reasonable time, however, to a centralized deresination facility (such as an existing chemical plant), it might be possible to keep the costs reasonable. The questions requiring responses are: (1) the technical feasibility of short-duration storage; and (2) the availability of deresination facilities at existing chemical plants. These two issues are easily subject to investigation and, if resolved favorably, could lead to a different and much less costly approach to stimulating the development of the guayule industry.

The Power of the Electorate

All of the above thinking and maneuvering bore fruit in a 1982 Budget request which passed review at both departmental and White House (OMB) levels. The stage was set, and real progress could begin!

Unfortunately, President Carter lost the election, and the new administration moved for large budget cuts. The proposed budget for all of the Innovation Initiative (not just the Resource Technology Program) was set at zero.

Conclusions

The above review of the Guayule Program highlights several points which may be of value to the study and execution of other programs of the federal government:

- Programs of the federal government are dependent upon personalities. It is necessary to have people who believe in a program and who are willing to commit their personal energies and reputations to its success. Without such personal commitment, a program will be ground into dust by administrivia.
- Personal commitment of officials is more likely if officials obtain the attention and support of the public and industry as they did in the Guayule Program. The effectiveness of this support requires better understanding of the budget process and the public's role in it.
- The easy way to promote progress on a government program is to spend money. Pressure for rapid funding, however, is likely to encourage unscrupulous operators as well as provide incorrect direction for federal efforts. There are frequently better alternatives than funding. These alternatives, however, take time to perceive, plan, and carry out.
- A follower of the rational approach to program management will be tempted to believe that OMB will be interested in the technology and industrial economics of the program, and that the budget process is one of rational argument. Experience in the Guayule Program teaches that anyone who believes they can outsmart or outargue OMB is on a sad road to disillusion. To do its job properly, the OMB staff develops high talents as a group of professional skeptics.
- The follower of the political school of program management may be tempted

in a different direction, that of building political support for the program, and strengthening the abilities of constituents to lobby in its behalf. This approach is both political suicide and illegal. An officer of an administration may not lobby against that administration. You may quit, if you find official policy significantly repugnant. To the public, however, you must always appear in the role of the "good soldier."

Civilian technology programs *can* work. Many of them, such as Guayule and Resource Recovery, can contribute greatly to the nation's security and economic development, and can build the type of public/industry/government cooperation which is increasingly needed in a rapidly changing and competitive world.

Bibliography

Arrow, Kenneth, "Economic Welfare and the Allocation of Resources for Invention," *The Rate and Direction of Inventive Activity* (Princeton: Princeton University Press, 1962), pp. 609–25.

Baer, Walter S., Leland L. Johnson and Edward W. Merrow, "Analysis of Federally Funded Demonstration Projects," Rand Corporation, April 1976.

Barfield, Claude E., "White House Views Intense Technology Hunt as Useful Exercise Though Few Projects Emerge," *National Journal*, May 6, 1972. pp. 756–65.

Bodde, David L., "Politics, Technology, and Management Education," *Technology In Society* 6:153–59 (1984).

Cyert, Richard and James March, *The Behavioral Theory of the Firm* (Englewood Cliffs, NJ: Prentice-Hall, 1963).

Eads, George, "U.S. Government Support for Civilian Technology: Economic Theory versus Political Practice," *Research Policy* 3:216 (1974).

Heclo, Hugh, *A Government of Strangers: Executive Politics in Washington* (Washington, DC: The Brookings Institute, 1977).

Katz, James E., "Planning and Legislating Technical Services: The American Experience," *Technology In Society* 4:51–66 (1982).

Magill, Kathleen P. and Everett M. Rogers, "Federally Sponsored Demonstrations of Technological Innovations," *Knowledge: Creation, Diffusion, Utilization* 3(1):23–42 (1981).

Guayule: An Alternative Source of Natural Rubber (Washington, DC: National Academy of Science, 1977).

Nelkin, Dorothy, *The Politics of Housing Innovation: The Fate of the Civilian Technology Program* (Ithaca, NY: Cornell University Press, 1971).

Nelson, Richard R., Merton J. Peck and Edward D. Kalachek, *Technology, Economic Growth, and Public Policy* (Washington, DC: The Brookings Institution, 1967).

Office of Technology Assessment, *The Role of Demonstrations in Federal R&D Policy* (Washington: DC: US Government Printing Office, 1978).

Schlie, Theodore W., "The Theoretical Basis for Government Support of R&D: Traditional Arguments and New Realities," US Department of Commerce, Second US-Japan Science Policy Seminar, August 24–26, 1981.

Yurow, Jerome and F. Cecil Brenner, "The Civilian Industrial Technology Program: A History and Evaluation," Report no. 1082 (Washington, DC: US National Bureau of Standards, 1969).

The Business of Technology:

A Board Guide to Profits and Progress

by

Francis W. Wolek

Directors & Boards, Volume 9 (No. 4), 1985, pp. 29-46.

SUMMARY

Technology is increasingly becoming a topic for consideration by corporate Boards of Directors as the costs of its development increase and the competitive impact of success and failure grows. This paper uses a survey of the history of technology (aircraft, steel, auto, etc.) to provide guidelines for Board members on the critical role of business judgment and vision in decisions affecting technological innovation. It especially focuses on the: (1) importance of convergences in technological and market forces, (2) the crucial role of managed learning by deploying technologies in early operations, (3) rules of thumb to estimate the costs and risks of R&D, and (4) the need to avoid greed and promote multi-firm prosperity from successful innovations.

Special Report

The Business of Technology

Part I: A Board Guide to Progress and Profits

by Francis W. Wolek

"America's High-Tech Crisis"; "A Bloodbath in Chips"; "A Technology that Could Remake Big Steel"; "Managing Technology: The Way to Win." These are headlines from a sample of technological articles featured recently in the business press. The message of the headlines is clear: technology is a potent force in modern business, a force which demands the attention of all with responsibility for corporate vitality and success.

This media hype about technology may, however, engender ambivalent feelings on many boards. On the one hand, the sense of threat and opportunity argues for a strong hand in technology decisions. On the other hand, the arcane language of science and technology and the image of the obscure genius suggest that the world of modern science and technology is reserved for specialists and is unavailable to the board.

Dr. Francis W. Wolek began his career as a geologist at Sinclair Research Laboratories. He was Deputy Assistant Secretary for Productivity, Technology, and Innovation at the U.S. Department of Commerce from 1977-1981. He is now Director of Research for the College of Commerce and Finance at Villanova University.

Directors & Boards, Volume 9(No. 4), 1985.

I intend to show that the board is uniquely situated to influence the most critical, technical issues facing the corporation. As a generalist who has dealt with policy issues cutting across diverse areas of science and technology, I have been forced to think generically about technology and its relationship with corporate strategy. The history of innovation has proven to be a useful lode of strategic thinking about technology.

Breaking Through

Popular thinking about technology focuses attention on breakthroughs which obsolete products and undercut markets. Big Decisions (should management get approval for those massive investments of financial and human resources?) and Big Worries (are the media correct in predicting the demise of your industry via invasion of a new technology?) abound. You're damned if you go ahead and end up with another loser like the autogyro; you're damned if you don't and miss out on a winner like the computer.

At first glance, the prospect for coping seems bleak: How can the board predict discontinuities in technology if the firm's own R&D staff has not; how can the board monitor the complex and secretive world of international technology; how can the board winnow the few, sound ideas from the many crazy ones. These and similar questions suggest that it might be best to simply accept vulnerability and make brainpower available for a rapid response to others' breakthroughs.

The history of technological innovation argues otherwise. Not only can the board play a critical role in understanding breakthroughs, but the knowledge gained provides needed insight for strategic evaluation of the company's R&D portfolio and management team. The story of the DC-3 is an illustrative example. [See sidebar.]

A friend recently related a "sad lesson" about scientists and technologists on the board. He had convinced his fellow board members to elect an internationally prominent scientist, only to find that the person acted as a businessman and eluded involvement on scientific questions. The DC-3 development shows us that the scientist was not being contrary, but smart! Understanding of the commercial context dominates understanding of the technological.

Understanding the generic characteristics of technology allows the board to think strategically about

technology. So armed, the issues are not what is the best way to design a propeller, or what is the solution to that annoying vibration problem, or what is the most useful theory of streamlining. These are issues for technologists and their managers. The issues on which the board must demand clear explanation center on the strength of the commercial context which determines success. Specifically:

- ☐ What is the direction of the converging *business* forces (market needs, supplier capabilities, public policies) and are they strong enough to create a new commercial context.
- ☐ In reference to this context, what are the *interdependencies* which determine the commercial and technological capability for a competitive performance?
- ☐ In reference to these interdependencies, what is the *competitive position* of the firm in existing talent, experience, and market position.

Technological overshooting

The firm may sidestep this need for business judgment and give its best scientists and engineers the freedom to choose. However, then it runs the danger of the technological overshooting which bankrupted Rolls Royce on the RB 211 jet engine. Sidestepping is also possible by sticking with safe technologies until the business context is clear. But then the firm runs the danger of undershooting commercial opportunities as did Boeing, which built on improved, military planes (the 247 was an outgrowth of the B9 bomber) when it had all the talent and knowledge Douglas used on the DC-3. The breadth and experience of the board place it in a unique position to provide an alternative: the vision and judgment needed for an ambitious and realistic objective.

Before going off the deep end on the wonders of technology, we must rein in tightly and remember why the

Power of Convergences: The Development of the DC-3

To most people, a breakthrough appears to be an inspiration of genius. At a point in time, a brilliant person shouted "Eureka!" and the new idea was born. The development of the DC-3, the innovation which initiated American preeminence in air transport demonstrates a different phenomenon — *convergence* of existing thinking to a new system.

The designers of the DC-3 integrated several existing technologies — variable-pitch propellers; movable flaps; edge-mounted radial engines; and air-body streamlining. Each of these converging ideas had been under development for 10 or more years and each had been incorporated in a commercial airplane (e.g., the Lockeed Orion, Boeing 247, Northrup Gamma, etc.). Each idea had improved the performance of airplanes. However, each had also disappointed designers by failing to yield the superior performance hoped for and necessary for commercial success.

Undaunted, each design team had continued working to perfect favored technologies, and the resulting sequence of improved models presented visible lines of development from which all could learn. Companies competing in the air-transport market were not only marketing improved models, they were also diffusing knowledge about aeronautical technology.

A key to understanding this successful convergence of technologies is that it was a change in the *structure* of air-transport technology. The DC-3 was neither a simple combination of four lines of development, nor did any particular feature determine its performance. The essential element was design as an integrated system: the design of each element was tied to the design of others. The DC-3 was more than creative emulation; it was an integration which required much in talent, experimentation, and practical knowledge of air transport.

The argument that breakthroughs are understandable may be interesting, but it does not deliver on the promise that the board is uniquely situated on technology strategy. The commercial interplay which paralleled the DC-3's technological development adds the necessary depth by showing that the DC-3 also emerged from a parallel convergence in *market* forces.

As interest in air transport grew, there was greater interest in larger loads, faster travel, and more economical operation. Greater interest also meant a need for airfields at secondary cities with shorter runways. Such were the converging market needs, and a reexamination of the technological convergences shows an interesting pattern: the converging technical ideas also, and not accidentally, satisfied such market forces (engines/payload, streamlining/economy, flaps and propellers/short runways).

The underlying message of the DC-3's development is this: Specialists in propellers or hydraulics were needed to design the next device, but experienced industrialists were needed to understand business trends and risk major resources invested in a new technology, a new form of technical partnership (with American Airlines), and new markets. The engineer can design the device, but the board is uniquely situated to appreciate the venture as a business and to assume the necessary risk.

experience, breadth, and judgment of the board are crucial. Our understanding of technological convergence does not dictate our business judgment. It is the other way around! The critical questions center on the commercial convergences which would create a business opportunity, and the convergences in a particular industry which could create new forms of partnership of complementary interests and capabilities. For these forces to be understood, the board and the firm require both knowledge gained in direct contact with other firms and experience gained from exploratory ventures. Until these steps have yielded a specific group of consumers or customers which can be targeted with a specific business capability, technological progress will remain laboratory novelty rather than competitive exigency.

Following Up

Creative breakthroughs which make and break businesses are the stuff of headlines. However, the investments a firm makes or fails to make in automated production can also determine success and survival. Process investments involve such large commitments of funds, professional effort, and time that they have had substantial impact — both in bankruptcies from overinvesting and big gains from determined adaptation to new demands.

The argument behind investments in production technology is typically that of productivity improvement. Most managers have faith that robots, computers, and semiconductor instruments will do it better, faster, and more smoothly. In all too many cases, however, the dreams of technological wonders go waning while the demands of creditors become pressing.

The work of economists of industrial processes provides evidence that the popular faith in productivity gains is a dangerous simplification. Specifically, they have found that new process technology generally does *not* yield productivity gains which provide an economic return greater than the cost of capital. In other words, companies which justify their slowness on grounds of inadequate return are right — as long as they stick with productivity as the sole source of return.

This analysis of process productivity is counterintuitive and disturbing. If you can't believe in productivity, what can you believe in? The history of process technology in the steel industry teaches some important lessons. Technologies such as the basic oxygen furnace, continuous casting, and the modern blast furnace continue to be highly regarded, despite the fact that their return from cost savings has not kept pace with the cost of capital (e.g., only 5–9 percent for continuous casting). Why the faith? The technologies have had a multitude of things going for them, both predictable and not, and most have not been evident until they were deployed in commercial use.

A simplistic response would be that companies should always invest in technology, because somehow, someplace, someone will find a payoff. If this were true then several steel companies would be heroes and not bankrupt. Instead, the task is much more demanding of commitment and hard work. Technologies such as continuous casting have not really been profitable, just essential for survival.

Adaptable technologies

Modern steel technologies have allowed companies to adapt to a different competitive environment than existed when the investments were made. The adaptation has come at a high cost and required many years. Product lines were changed, new material balances used, supporting technologies tied in, people reorganized, and management adapated to new needs and skills. The key to the technologies themselves was they, unlike predecessors such as the open hearth, were *adaptable*.

Applying these lessons of history to the concerns of the board requires additional insight; specifically, answers to such questions as:

☐ Some technologies have more synergistic payoff than others. How do you know the difference?

Worry About Complacency

An important time for the board to pressure management occurs when new competitors develop a potentially critical and competitive technology.

At such times, the board may have to deal with a complacent management which argues that the competitor is more a joke than an alternative. Arguments will be made that the firm's technology was never improving more rapidly — gas lights were undergoing their most rapid improvements when the electric bulb was introduced — and that the new technology doesn't really work (ball-point pens kept skipping and leaking).

The board must not be put off by such arguments, which typically apply to innovations before learning from use improves them into unbeatable replacements.

As to who is crazy enough to give a crude technology its birth, the usual answer is operatives in small market niches (diesel locomotives were first used in switchyards where fire and steam created hazards). Guglielmo Marconi benefited from another common pattern: accidental discovery of a market niche. He had dreams of a monopoly over a new system for international news broadcasts. Instead, his radio earned respectability, capital, and experience meeting new regulations for ship-to-shore communications — an unforseen, legislative response to spectacular sinkings as the *Titanic*.

☐ How can you tell if the plan for a technology's adoption is both consistent with the market and financial position of the company and includes the time needed for absorption of synergistic benefits?

☐ How can you be sure that the organization will persevere and learn how to integrate a new technology?

The board member's ability to differentiate technologies with synergistic potential depends on experience with the system of procedure, material flow, and driving requirements which structure the firm's operations. Such experience is essential to understand where the three hallmarks of critical technologies apply: adaptability to future change; simplification of the system; and/or significant impact on people.

Competing designs

A characteristic of critical product or process technologies is that they involve such large commitments (designing all the system interfaces, readjustment as application divulges more ramifications, managing an interdisciplinary team with different languages,' etc.) that the firm must often choose one of several, competing designs. Such critical choices have determined the success of nations as well as companies. For example, in the field of atomic power, the United States chose pressurized-water technology and won the early race to commercial markets while the British chose the technologically more sophisticated high-temperature gas reactor.

One difference between companies which reap profit from technology and those which reap sterile knowledge is that profits flow from *managed learning*. The most important knowledge gained on critical technologies will not be from the lab, but from the shared experience of process engineering, sales, materials management, and line supervision working together from initial analysis to fully integrated operation. That is, profitable experience centers on the "*know-how*" of technology — how to keep it in reliable operation, how to adapt it to other technologies, how to create a new product line integrating the new capabilities with market opportunities, how to build a team of people committed to the technology.

Reason for failure

Firms which fail, despite investments in perfectly marvelous technology, are those which focus on productivity gain, believe that machine installation is machine utilization, and rely solely on engineers for implementation. Those steel companies which delayed adoption of critical technologies typically believed their world-class engineers guaranteed a competitive ability to respond quickly once the technology was proven by others. Such abdication of management in favor of engineering overestimates the importance of abstract principle and deprives the engineers of the critical support they need.

Change in people's self-perceptions, product lines, and operating practices do not follow the visionary pace of dreamers, journalists, and missionaries. Instead, the history of technology teaches that change is so long and meandering that it is helpful to think of it occurring in stages.

The board's fiduciary responsibilities for the financial and human resources of the firm place it in a unique position to critically review plans for the deployment of process technologies. In confronting the contest of such reviews, the board should find the firm emulating the practice of "roll outs" used in marketing new products. That is, a phased deployment, involving:

☐ First, a test on existing tasks to learn the technology's operating characteristics (test marketing to learn consumer requirements).

The Need for Champions

Full commitment and active involvement by top management are necessary for the success of critical technologies. This is one of the primary lessons of the history of computer technology.

Only a mother can love an ugly baby, and the computer, like many critical technologies, was ugly in infancy. It took fortitude — and government contracts — to persevere when the general view was that there was no demand, no dominant design, and substantial risk of loss.

Top-level champions like Thomas Watson were needed to commit the funds (many companies starved their early efforts), absorb huge losses on experience-building contracts (the "Stretch" computer cost over 10 times its contracted price to the Atomic Energy Commission), build quality peripherals (many contracted these out), approve risky marketing plans (some would not accept the risk of leasing to customers), avoid destructive disputes between technologists (the choice of transitors vs magnetic amplifiers was a critical choice which had warring advocates), and be dedicated to consistent improvement over time (several companies tried to market obsolete technologies).

The board should not play "bet your company" and approve a dream technology unless someone who has already arrived is willing to play "bet your career." The personal commitment of champions with top responsibility is essential to command the respect of financial sources, be able to objectively choose between technologies advocated by people competing for the top, implement marketing and organizational plans that make the technology effective, and persevere through unexpected adversity.

[ ] Second, commercial use in a market niche to understand integration needs (first market entry to learn how the product relates to distribution and competition).

[ ] Third, focused use of the technology on a product group to translate lessons into a working organization (regional focus to build a marketing system).

[ ] And fourth, adaptation for use across product areas (national marketing of a product line).

"Use it or lose it" is the password on critical technologies. If deployment does not occur with the active guidance of top management, the firm will lose its competitive position regardless of the sophistication of its technologists. Using technology in practice is a process of:

— top-down highlighting of potentially critical technologies;

— phased deployment in operations;

— managed learning of benefits;

— bottom-up communication of refinements, interdependencies, and resource needs; and

— top-management structuring of the organization, time table, and directions for change.

Maintaining the Lead

The history of innovation also imparts lessons on the normally long periods of steady improvement in an existing technology. For example, the full impact of a critical technology takes many years and involves many steps of modification and refinement to fit many changes in the market. Thus, it should be no surprise that most of corporate R&D is a process of *incremental* improvement based on actual experience. Incrementalism — e.g., accumulations of 10-percent improvements in cost, adaptations of design to more varied conditions, resolution of problems as operations are scaled-up in volume, etc. — is the life blood of corporate R&D.

We also know that breakthroughs result from accumulations of converging developments which originate in many different organizations. Thus, it should be no surprise that much of R&D is a process of "building windows on the world" — developing the reputation and talent to have access to progress at other organizations.

Finally, given the importance of building an expert team to assure managed learning, it should be no surprise that most organizations become committed to their own specialists and their own pattern of progress. The functional narrowing of perspective (denounced as the NIH or "Not Invented Here" syndrome) sometimes has the disfunctional consequence of rejecting ideas originating elsewhere. Indeed, entrepreneurs who had to fight unreasonable resistance to establish their technology have turned out to be some of the most narrow-minded opponents of the next wave of technology: Western Union resisted the telephone, AT&T resisted radio, Marconi Radio resisted radio communication of voices, and RCA resisted FM. (However, the resistance of RCA to FM, and computers, also was partly brought about by the magnitude of their commitment to television.)

Big bucks, snails pace

The technology expert generally reigns supreme during the normal pattern of incremental progress in

Risk and the 'Rule of Sevens'

An undeniable board function is validating the resource commitments required for success. Economists who have studied R&D have found an exponential increase in resource needs which may be simplified with a "Rule of Sevens": If an incremental technology, to be sold through existing channels, costs $1 million for R&D (i.e., to a set of specifications), it will cost $7 million for design (i.e., completion of an operating prototype), and $7 million more ($15 million in total) to produce the first commercial unit (i.e., technology refinement, plant tooling, documentation, promotion planning, training, etc.).

Furthermore, these estimates do not recognize the working-capital requirements of market expansion — e.g., special promotions, training the service organization, stocking the pipeline, production scale-up costs, etc. — which precede significant profits.

Studies of the lead time in innovation are also enlightening. If the time to complete the research was one year, the time to the first unit will be three years, and significant profits will not start to flow for another two years (i.e., a total of five years). Furthermore, any good business leader has learned the hard way that it is foolhardy to believe it will never rain on your parade.

Risk is one of the fundamental characteristics of innovation. It seems helpful to factor this overall risk into the risks of: technological success (i.e., the thing will work); commercialization (i.e., management believes it continues to make competitive sense and authorizes deployment); and commercial success (i.e., the customers like it and use it). On average, the probabilities of an incremental advance successfully completing each stage are: .6, .6, .7, respectively, with an overall result that only one in four projects is successful ($.6 \times .6 \times .7$).

These data are sobering indeed, but even more so when we realize that the definition of success was only that the project will get the firm back to where it started (i.e., it returns its cost at a rate equal to the cost of capital).

technology. Insofar as changes are incremental and the firm has built a tight organization of mutually dedicated experts, this situation may seem to provide valid relief for the board. Don't fix what isn't broken and don't tamper with success.

However, it is not uncommon that executives and/or technologists become impatient with the pace and direction of progress. What may then emerge is a Big Project — the "exciting, new direction that will shake the industry." Now the board is heavily involved and must not be lulled by smooth progress in the past.

Not radical enough?

To be sure, questions about convergences, critical linkages, life-cycle planning, etc., are important. But what if management's answer is that the change is big, but not radical enough to obsolete the existing structure.

Be very, very skeptical! Management can easily underestimate the synergistic effects of change and overestimate existing talents to process it. If it is big enough to shake the industry, it is critical enough to require phased deployment, planning, and market convergence.

Technological innovation is risky, expensive, and long. Innovation has made and broken many firms. The resources required are more substantial than many realize. Technology has great potential, but only the foolhardy ignore reality. Since foolhardy organizations may not survive, there have to be ways of adapting to these realities. One such adaptation has already been noted — R&D becomes an organized process of incremental advance, so that its lessons are cumulative and even failures yield useful knowledge.

One problem with incremental R&D is that people who share a common commitment can become provincial in their thinking. It is nice to have an R&D lab which believes it has no peer, but this is also a clue that the company may have become muscle-bound.

Beware and never accept the claim "We're the best in the business and have nothing to learn from others." The world of international science and technology is entirely too rich and complex to ever make such a statement valid. The technology of unit-body construction crossed and re-crossed the Atlantic many times — Vauxhall used it in 1903, Renault, Fiat, and Peugeot provided a model for U.S. engineers, and Ford and Budd provided designs and tooling for Volkswagen. So too are suppliers an important source of technologies — disk brakes, solid-state alternators, paint and lacquers, etc. — which require continual redesign of process and product features.

An irreplaceable role for R&D is to integrate the company with the network of experts whose interactions are determining the rate and direction of innovation. Work at the cutting edge of progress takes place in interpersonal interactions between reputable people and is only shared with those who can give information as well as receive it and who have the hands-on experience needed to ask intelligent questions and understand expert replies. In short, the firm needs top scientists and engineers and needs them to be in touch with other leaders throughout the world.

Making Profits

The development and early commercialization of a major technology will undoubtedly be a trying, unpredictable, and expensive process of learning which will thoroughly test a board's perseverance. Certainly when these trials have been passed, and wisely marshalled resources have produced a brilliant technology, the board may sit back and watch the profits roll. Sorry to say, such thinking implicitly assumes that scientific and technological issues determine the success of innovations. The posterior trials of technological development turn out to be as equally demanding as the prior.

The history of technology is replete with tragic cases of brilliant people who persevered through adversity to produce terrific technologies on which others made millions. In most cases, failure followed from errors in business judgment due to overestimating the commercial value of brilliance, underestimating the competition for profits, and greed.

The case of a bankrupt company featured on Public Broadcasting's "Enterprise" series highlights the importance of business judgment in selecting the correct home for a technology. The company had pioneered an innovative computer terminal in

Director's Duty: Stamp Out Greed

Brilliant technologists may be covetous people who do not want to share profits, equity, and managerial control. If you are on a board that must deal with this attitude, your responsibilities to bring about change are great, for the history of innovation suggests it could turn out to be a spiteful and self-destructive failing.

For example, Eli Whitney is widely regarded to be one of the more brilliant luminaries in American technology. However, instead of earning millions from the cotton gin, it put him in the poor house. When his invention won spectacular acclaim, he rejected many proposals to license the technology to others and insisted on personal control of the technology and its markets. Unmet demand, because Whitney couldn't grow fast enough, is a powerful vacuum; and Whitney found that others modified his designs to build their own gins. He wrote blistering letters and fought back in court, but only the lawyers won. He went broke.

the days when office automation was in its infancy and found a niche that no one had predicted. Sales soared, officers seemed to become millionaires, and visions of a future IBM clouded the horizon. Sure of their technological brilliance, management turned down repeated offers of acquisition. They felt they had the brains to make their own home base and were not going to sell their future short.

The story is an oft-told tale of people who overestimate their smarts and underestimate the resource requirements of a successful business. The story ended in bankruptcy after a few bright years of valiant efforts to meet the competition and to fund rapidly expanding markets.

Existing cash cow

What many forget about phenomenal successes like IBM, Texas Instruments, and Xerox is that companies need considerable resources to build an organization and competitive strength. In each of those cases, the company had an existing cash cow to provide a stable platform of capital generation and a service organization.

Maybe the worse thing that can happen to a technology-based company is to have its products succeed brilliantly and its markets develop rapidly. Such results attract predators and generate punishing requirements in management and capital.

The adaptive response of a free market to the realities of success has been an evolving system of relationships between big and small companies. One element is the buyout — now being experienced by the small companies that absorbed the high risk of innovation in robotics. They proved that a market exists and started building know-how in special niches such as automated painting. Now that the start-ups are facing the rigors of big-time competition and the resource requirements of national markets, they are being acquired by the GMs, GEs, and Westinghouses.

Invent it, sell it

This story, repeated in many fields, yields one entrepreneur's motto: "Invent it, grow it, and sell it!" Since the rewards to entrepreneurs in such buyouts are substantial, this system has been an engine of technological leadership. The system works. The board and top management's responsibility, then, is that of timing.

Competition is the fundamental force in a free-market system, because free competitors will try anything legal to do each other in and become a hero by appropriating profits. Unfortunately for technologists, their background — often in the academic world where the originator of ideas is the hero — and their own fascination with gadgets can lead to underestimation of the prowess of businesses hunting profits.

The history of competitively successful innovations repeatedly demonstrates that ideas are easily discov-

Continued on page 46

Readings in Technology Management

The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry, William J. Abernathy, Johns Hopkins University Press, 1978.

The Electric Lamp Industry, Arthur A. Bright, Macmillan Co., 1949.

"Strategic Responses to Technological Threats," Arnold C. Cooper and Dan Schendel, *Business Horizons*, February 1976.

The Development of Markets for New Materials, Raymond E. Corey, Harvard University Graduate School of Business Administration, 1956.

Petroleum Profits and Progress, John L. Enos, M.I.T. Press, 1962.

"Two Weapons," James Fallows, in *National Defense*, Random House, 1981.

The Sociology of Invention, S. Colum Gilfillan, Follett Publishing Co., 1935.

Evaluating Technological Innovations, Bela Gold, Gerhard Rosseger, and Myles G. Boylan, Lexington Books, 1980.

"The Computer Industry," Barbara G. Katz and Almarin Phillips, in *Government and Technical Progress*, edited by Richard R. Nelson, Pergamon Press, 1982.

The Soul of a New Machine, Tracy Kidder, Avon Books, 1982.

Ten Innovations, Christopher Layton, Crane, Russak & Co., 1972.

Invention and Innovation in the Radio Industry, W. Rupert MacLaurin, Macmillan Co., 1949.

"Production of Microbial Protein: A Study in the Development and Introduction of a New Technology," Pauline K. Marstrand, *Research Policy*, Vol. 10 (1981).

"Technological Change and the Theory of the Firm: The American Locomotive Industry, 1920–1955," Thomas G. Marx, *Business History Review*, Vol. 50 No. 1, 1976.

The Technical Development of Modern Aviation, Ronald Miller and David Sawers, Praeger Publishers, 1970.

Men, Machines, and Modern Times, Elting E. Morrison, M.I.T. Press, 1966.

Patterns of Technological Innovation, Devendra Sahal, Addison-Wesley Publishing Co., 1981.

Revolution in Glassmaking, Warren C. Scoville, Harvard University Press, 1948.

Continued from page 35

ered ("reverse engineering"), patents can be designed around and fought in court, and technological superiority can be neutralized with business savvy (marketing, service, control of distribution, etc.). In short, the rules of the game when the board considers the firm's competitive position are:

☐ Neither trust the cloak of secrecy, nor let people photograph your technology.

☐ Be prepared with the funds and allies for a patent battle.

☐ Never allow management to underestimate the competition.

In Future Issues

The CEO as a Global Executive
A Roundtable discussion on key issues involved in the management of international operations.

The Case for Restricted Stock
An examination of the features and strategic uses of this long-term incentive arrangement.

The Art of Building a Successful Company
A CEO reviews his game plan and battle scars from starting up three high-tech companies.

A New Era for Foundation Boards
Fiscal belt-tightening should stimulate a growing reliance on performance evaluation in this sector of trusteeship.

The Pros and Cons of Union Members on Boards
Leading experts offer some advanced thinking on the issue.

Lucrative offers

The fact is that companies do pay handsomely for patent rights and do reward successful entrepreneurs with lucrative buyout offers. The buyouts are especially handsome when the entrepreneur has the time and skill to build an organization with competitive know-how. However, it is always best to assume such payments will not be greater than the costs of getting around a proprietary position. In short, unless a firm has the millions for a long market and legal battle, it shouldn't be greedy.

Technological innovation is a team effort from start to finish. Scientists and engineers who are not tied into the network of leaders in their field are sure to miss the boat. Entrepreneurs who fail to build know-how through working with users and suppliers will end up dead in the water. Boards who understand that technological success is a team effort are prepared to share handsomely.

Leading the Way

I have been very privileged in my life to travel widely among the centers of technological progress in America. The sophisticated use of man's knowledge I have witnessed, the ingenuity in adapting it to new needs, and the genius in building the resources of people and capital into competent competitors have been awesome. The ideas, the sacrifices, and the repeated attempts to solve problems with the raw tools of intelligence and back-breaking effort just don't stop.

America is blessed with the people, riches, and social system to be the engine of progress for all mankind. The rest of the world knows that, gains excitement from us, and refuses to let us shirk our responsibilities. We have no choice as a nation; our own dreams and those of the world will not let us off the hook of discovery, adaptation, and growth.

You as a corporate director also have no choice. You cannot stop society from molding the corporation into an effective force for its aspirations. The social pressures, raids from all quarters, and internal demands of people are no passing fad. We haven't seen anything yet, and our ability to innovate will be as much a cause as a source of relief.

Just as you cannot stop the dreams and progress of society, you cannot stop the progress of technology and the ingenuity from which it springs. You may personally stop and get off, but the competition and opportunity which are at the heart of our system will replace you with others who will welcome the challenge.

Sense of opportunity

My intention has been to inspire the confidence and pride that are needed to use your unique position to serve. As a group, corporate directors have the richness of experience and breadth which is essential to understanding the convergences, nature of building know-how, and importance of world-wide learning. As senior officers, you have the sense of wonder and opportunity and the balanced understanding of business needs to inspire professionals. You have the freedom from operating responsibilities to listen and make the critical decisions which transcend organizational boundaries. You have the ability to understand technology and to place it in a positive context of shared progress. And, in a land where ownership is truly in the people, you speak for all as industry's stockholders.

A board of directors has a unique and special contribution to technological progress. What we need from you is the vision, energy, and the courage to make it. ■

DISCUSSION

Mr. WALGREN. Thank you, Dr. Wolek.

Are you concerned about the trend the first witness mentioned to restrict the transfer of information among certain Government-funded research programs if we are to have this kind of openness that you are emphasizing in an interactive sense? Some of the limitations on publishing that we have seen from the Defense Department would be inconsistent with that, wouldn't they?

Dr. WOLEK. Absolutely. But I am less concerned about the limitations on the publishing. I have no problem with asking authors to send in a paper and check it over and look for things in it that might be detrimental to national security.

The whole philosophy, though, behind that move is what bothers me, because how can you control what the people say in their interactions at conferences, during their visits to other facilities, during the visits that they get from other facilities? It is impossible to control that type of thing, and that is where you get real transfer of know-how, the understanding of the type of thing that never appears in the papers.

The only way that you can stop the transfer of know-how is to stop the interaction. What I am saying is, as soon as you stop the interaction, you stop the effectiveness of the applied scientific work in the mission agencies.

Mr. WALGREN. I see. Let me ask the gentleman to my right and left if they would like to raise any subjects. If not, we should close at this time.

OK, on behalf of the task force, let me express my appreciation of your being available for this work and these discussions. We certainly appreciate your contribution to it.

Dr. WOLEK. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you. Our hearing will be adjourned.

[Whereupon, at 12:18 p.m., the task force recessed, to reconvene on Wednesday, October 30, 1985, at 8:30 a.m.]

APPENDIX 1

TESTIMONY OF JOSEPH M. PETTIT, OCTOBER 27, 1985,
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

(IN LIEU OF SCHEDULED APPEARANCE, OCTOBER 24, 1985)

By way of introduction, I am Joseph M. Pettit of Atlanta, Georgia. I have been president of the Georgia Institute of Technology since 1972. Prior to that I was on the faculty of Stanford University from 1947-1972 , serving as dean of the School of Engineering from 1958 to 1972.

I am one of the eight original presidents on the DOD/University Forum. I was a member of the National Science Board during 1977-1982. I am a member of the National Academy of Engineering, and chairman of its Education Advisory Board.

The interest of your current hearings extends over a wide range of matters involving the research roles of the mission agencies. I was asked to comment in particular on some aspects which have been under consideration by the DOD/University Forum. Even these constitute a wide range, and I believe my contribution to the hearings might be most useful if I concentrated on one issue alone.

I should like to comment on the appropriateness of DOD, as a mission agency, in supporting basic research in the universities. A question which is sometimes raised is, might it not be better for such research to be supported only by a specifically designed agency, such as the current National Science Foundation, or perhaps a wholly new department? My answer is no: I support the current arrangement instead. Let us encourage the mission agencies, including DOD, to carry a solid responsibility in helping to support basic research in the universities.

Historically, prior to World War II, the military agencies which now comprise the Department of Defense, did their research largely through their own laboratories, and most it was applied, or mission-oriented. Little attention was paid to building up our knowledge base, upon which future defense systems would depend. Little use was made a national resource well suited to extending our knowledge base in science and technology, namely the professors, researchers and students in the universities. During WWII this pool of talent was mobilized in several wartime projects and laboratories - to great effectiveness. But after the war these persons returned to the university world - which has its own unique environment. Universities are institutions of higher learning, where fine minds come together to learn and teach, and especially to extend the frontiers of knowledge in the various disciplines. Indeed the universities are the strongholds of the disciplines, in which are built the foundations upon which interdisciplinary work in applied research and development can best be done, including of course that which will later be

carried out in the mission oriented work of the various Federal agencies.

This national resource in the universities was, at the end of WWII, newly appreciated by many, and articulated by Vannevar Bush and others. A new agency was proposed for engaging this resource, and in 1950 there was finally established the National Science Foundation. But in the interim after 1945, the defense agencies stepped into the vacuum, led by the Office of Naval Research. They extended the previous horizons of the defense establishment as to the range of research which should be supported. They established new contracting mechanisms well suited to working with universities, as opposed to their usual dealing with defense suppliers of goods and non-research services. Speaking personally, I had a very satisfactory experience with one of Stanford's first ONR contracts, commencing in 1947 and extending for eleven years.

As the other agencies, Army, etc. joined the ranks of research supporters, there developed a cadre of technical contract officers, dedicated to support of basic research, though always with knowledge of the applied needs of their agency. Rapport with those of us in the university developed well, and much was accomplished. Finally, when NSF was established in 1950, its officers merely joined the already existing group of informed contracting officers.

I refer to these officers as a "group," because they did not work in isolation from each other. We had annual meetings on the campus, to bring them up to date on research results of the past months, and our suggestions for continued work. One or another of them would usually pick up on the worthy suggestions, perhaps one of them who saw particular relevance to the development work in his agency, but sometimes merely the one who happened to have the budget money at the time. But on one or more occasions some one of the contracting officers seemed to possess a certain unique vision or intuition that caused him to pick up support of an idea that later proved to have wide value, far beyond the needs of his own agency.

The point to this narrative is that wisdom as to which of the infinite number of possible avenues of basic research might be promising for support is widely distributed among many individuals and agencies. The nation and the universities themselves are well served by having a diversity of sources of support.

A final point on the diversity of wisdom. Some of this wisdom resides in the universities themselves, of course, and if we could have a little "venture capital" to pursue some potentially valuable new initiatives, the whole enterprise would be well served. Thus I would urge that we be allowed the equivalent of the Independent Research & Development (IR&D) expenses permitted

to industrial contractors. At Georgia Tech, a few percent of our approximately $90 million of sponsored R&D would facilitate the exploration of some new ideas that might later become significant contracts themselves.

Another point of view on basic research derives from a now well established consensus that a small fraction of corporate or federal expenditure should be an investment in the future, through research and development. This philosophy could well be a part of the thought and responsibility of each Federal agency, including especially the mission-oriented ones like DOD.

Finally, the financial resources to do this must be maintained at adequate levels. We have been much concerned with this in the DOD/University Forum. In DOD budget parlance, it is the 6.1 and 6.2 monies that are the most significant for university research. The total amount has not been great, and it declined seriously during the 1970s. This past year, through the "University Research Initiative," some of this loss was restored. This must be continued. Basic research money is always in jeopardy because of competition with expensive projects with immediate urgency. Somehow it seems easier to postpone the future. But the future cannot be postponed nor predicted.

The continued support of members of this House Committee on Science and Technology will be much appreciated.

APPENDIX 2

R&D LABORATORIES' ENVIRONMENTAL CONTEXTS: ARE THE GOVERNMENT LAB - INDUSTRIAL LAB STEREOTYPES STILL VALID?

Michael Crow
Department of Political Science
and
Ames Laboratory
Iowa State University of Science and Technology
Ames, Iowa

and

Barry Bozeman
Department of Public Administration
and
Technology and Information Policy Program
The Maxwell School
Syracuse University
Syracuse, New York

R&D LABORATORIES' ENVIRONMENTAL CONTEXTS: ARE THE GOVERNMENT LAB-INDUSTRIAL LAB STEREOTYPES STILL VALID?[1]

> The government research organization is not troubled by the types of pressures that afflict the industrial or university research laboratories. The government laboratory is not concerned with either seeking to contribute to corporate profits or contributing to fundamental knowledge in a highly competitive publication race. [Marcson, 1972: 175]

Introduction

Stereotypes are an often useful shorthand. In the making of science policy, as in much of human endeavor, stereotypes can facilitate communication and decision-making by reducing the need for elaborate description and qualification. Consider for example the "basic-applied research" stereotype. It is not a precise term yet there is enough commonly held meaning in the distinction to warrant its use not only in casual discourse but in public policy as well.

Our study examines another stereotype, one almost as venerable as the basic-applied convention. The concern here is with the stereotypes pertaining to the environmental setting of R&D labs, particularly assumptions about differences between government and private labs. The stereotypes associated with the government-private lab distinction are based on concepts somewhat less murky than basic-applied research.[2] It is possible to identify some R&D laboratories which nearly everyone would view as government labs and others which nearly everyone would view as private. But of course, the clarity of concepts and the validity of stereotypes bear little relation. Even if one perceives that one lab is clearly a government lab and another is clearly private, one is not required to assume that the former is not market-driven and the latter is immune to political control.

One might well ask why the government-private laboratory stereotype, a comfortable and apparently useful simplification, should be subject to scrutiny. Our answer is two-fold. In the first place, there have been widespread societal changes in organization forms and environments (Aldrich, 1979; McKelvey, 1981; Pfeffer and Salancik, 1978) and it is unlikely that R&D laboratories have been unaffected by these broader trends shaping the structure of organizations. The emergence of new forms of organization has been widely documented (Sayles and Chandler, 1971; Chandler, 1962; Evan, 1966; Walsh, 1978) and, more specifically, the blurring of traditional government-private organization forms has received much attention (Bozeman, 1984; Fottler, 1981; Allison, 1983; Rainey, Backoff and Levine, 1976; Muslof and Seidman, 1980). R&D laboratories have not been immune to the process of organizational change as illustrated by the proliferation of cooperative and interorganizational research operations that have recently developed (Nelkin, 1972; Farris, 1978; Rothwell and Zegveld, 1982; Bozeman and Link, 1983; Reppy, 1977; Toren, 1978; Mowrey and Rosenberg, 1982). But the validity of government-private lab stereotypes is not an issue of concern only to students of organization change. Public policies are made on the basis of assumptions about the distinctive competencies, liabilities, and performance of labs in various institutional settings and environments. If these policy relevant assumptions are based on worn, threadbare stereotypes it is worth knowing.

Our examination of the environmental context of R&D labs is presented in two sections. In the first section, 250 R&D laboratories are classified first according to "ownership" (i.e. the conventional

public-private distinction) and then according to the "publicness" of organization environments (defined in terms of governmental influence resulting from government funding) and "R&D product category" (defined in terms of the market-orientation of the R&D output). This taxonomic effort concludes with the presentation of a conceptual framework applicable to R&D laboratories regardless of ownership type. In the second section, 32 detailed case studies are examined and classified in terms of the conceptual framework developed in the first section. From this analysis, a number of hypotheses and preliminary conclusions are generated about the effects of environmental context on R&D laboratory behavior. The paper concludes with a brief elaboration of the significance of the findings for R&D policy.

The Changing Environmental Context of R&D Laboratories

Students of R&D management have, by and large, been more attentive to the structure and design of the lab than to its environmental context. Studies examining such issues as communication (Allen, 1970, 1977; Moser, 1983; Stahl, 1975; Stephenson, 1971), coordination (Evan, 1966; Stahl, 1978; Marquis and Straight, 1966), and productivity (Irvine and Martin, 1980, 1983, 1983a; Andrews, 1979; Argyris, 1968; Stahl, 1977; Box and Cotgrove, 1968) have focused on the behaviors within individual labs and given scant attention to interorganizational relations or other such environmental interactions. The effects of environmental context on R&D labs have not often been examined and typically, assumptions about environmental influences on behavior are based on conventional wisdom and are not the target of systematic inquiry.

Simon Marcson (1960, 1966, 1966a, 1968, 1970, 1972) is one of the few scholars who have considered the impact of environmental context on R&D labs and much of his work is supportive of traditional stereotypes. In a 1972 study, Marcson identifies four basic environmental settings for organizations engaged in research: industrial, governmental, university, and non-profit. Each of these contexts is based on the formal legal status ("ownership") of the labs. Marcson argues that ownership of the R&D lab is the most critical variable in predicting organization behavior.

Marcson's treatment of the ownership variable is based on traditional assumptions about differences between public and private organizations. If a laboratory is owned by an industrial concern it is assumed that it will behave according to the standard rules of the firm in the market. If a laboratory is owned by a government agency, it is assumed that theories about bureaucracy, political decision-making and other political economy related theories prevail. The use of an ownership-based taxonomy for reclassifying R&D laboratories is pervasive in the literature (Pelz and Andrews, 1966; Fusfeld and Langlois, 1982; and Bigoness and Perrcault, 1981). Even the few comparative studies of R&D laboratory performance focus largely on differences based on public-private sector ownership (Stephenson, et al., 1971; Evan, 1966; Marcson, 1972; Loveless, 1985).

Ownership and Environmental Context

We assume, with Marcson (1972), that the environmental setting of an R&D laboratory is a vital determinant of its behavior. But the traditional ownership distinction, based as it is on formal legal status of

the organization, is an incomplete and in some ways misleading indicator of environmental context. Particularly inappropriate is a strict dichotomy between government and private labs. Ownership type does not inalterably determine R&D type and product, management structure, or effectiveness and efficiency. Certainly there is likely to be similarity among, say, government-owned labs, but there is also much diversity and, more to the point, certain government labs are more similar to privately-owned labs than to other government labs.

The recent history of R&D labs in the United States illustrates that ownership is often a poor guide to behavior. Consider the fact that since 1940 several completely new forms of R&D organizations have evolved. It is now not uncommon to find on a university campus an industrially funded proprietary research center, a joint industry/ government funded generic research center, or a government owned university operated research center. Similarly, in the 'private sector,' high levels of government support and control of the conduct of research in industrially owned R&D laboratories has become commonplace. As a result of these changes, it should not be surprising that it is becoming increasingly difficult for both scholars and policymakers to grasp the complexity of the R&D laboratory network. Furthermore, it can be expected that with the passage of such legislation as the Bayh-Dole Act (PL 96-517) and the Stevenson-Wydler Act (PL 96-480) that R&D laboratories will continue to change from the stereotype of being either a government lab or an industrial lab. As a result of both of these Acts, many 'government labs' are not only very much in the business of technology transfer, but are becoming increasingly subject to some of the

57-279 O - 87 - 26

same market viscissitudes as traditional private sector labs (Department of Energy, 1984; Department of Commerce, 1984). Presently, scientists in U.S. national laboratories are able to share in the profits of patents they produce and the pecuniary incentives in public and private labs are becoming more alike (Technology and Information Policy Workshop, 1985). Marcson's (1972, p. 173) observation that research organizations in different environmental settings "develop an atmosphere or climate within which the individual functions" is as true today as ever, but one cannot conclude that ownership type is the central feature dictating atmosphere.

Further complexity is introduced by the emergence of new forms of organization (such as the government sponsored enterprise and the multiple organization enterprise) and the formal partnerships among government, industry and university labs. The government-owned, contractor-operated form has a relatively long history (e.g., Brookhaven National Laboratory, Oak Ridge National Laboratory) and more recent innovations in organization forms (e.g., the Federally Funded Research and Development Center, state government-financed R&D "incubators") have further blurred the sectors and, consequently, rendered the ownership distinction more problematical.

"Publicness" and Environmental Context

The breaking down of sector distinctions does not imply that the "publicness" of an R&D lab is no longer significant; instead it suggests the need for a publicness concept based on something more than ownership. An approach developed by Bozeman (1984) provides one means of moving beyond overly simple ownership-based classification of environmental

context. According to this scheme, both industrial and governmental organizations are assumed to operate on a mix of authority types; publicness is measured in terms of the organizations' proportions of influence by political and economic authority. Thus, one might expect an R&D lab at an an aerospace firm which receives 90% of its R&D revenues from government contracts (and is thereby subject to a variety of government constraints) to behave differently than one with little or no R&D revenues from government contracts. Likewise, a government R&D lab which depends heavily on user charges and other quasi-market funding mechanisms might behave differently from one that receives all its funding from discretionary appropriations processes. Indeed, according to such a conceptualization of publicness it is theoretically possible to view a given industrially owned organization as "more public" than a given government owned organization. It is possible to describe the degree of publicness of any organization, even those of ambiguous formal status.[3]

Classification Scheme for the Environmental Context of R&D Labs

The classification scheme employed here focuses on two variables: publicness and R&D product type. These variables are viewed as a simple proxy for the extent to which the organization is influenced by, respectively, political authority and market authority. A nine cell classification matrix is established which provides for the categorization of R&D laboratories according to the two taxonomic variables of interest.

The Publicness Measure

The term publicness could be used to refer to any of a number of characteristics of an organization. As mentioned, the term public organization is often used to refer to government organizations, it is descriptive of the formal legal status of the organization. In economics, public is used to describe the economic character of goods and services. In political science the term public interest is used as a normative indicator of the organization's role in society. We have chosen a measure of publicness which, of necessity, excludes much of what is denoted by the term. But our purpose is to develop a measure which (1) can be applied to any R&D organization, (2) is not confused with normative assumptions, (3) is easily measured, but, at the same time (4) seems to capture an important property of R&D organizations.

Our simple measure of publicness is the percentage of government financing of the organization's R&D effort. In choosing this measure we are assuming that government financing equates, at least to some extent, with public influence. this assumption is not patent but there is reason to believe that it is a plausible assumption (Pashigian, 1976; Baumol and Oates, 1979) and, moreover, one purpose of this study is to provide an indirect test of the assumption.

Using the percentage of public financing as a measure of publicness enables an interval level of measurement. However, at this state of conceptual development we determined that an ordinal measure might be more appropriate. The following categories are used to develop an ordinal measure of publicness:

-- High Publicness: 76-100% of research funded by government agencies.

-- Moderate Publicness: 26-75% of research funded by government agencies.

-- Low Publicness: 0-25% of research funded by government agencies.

While this simple measure is not an entirely satisfactory indicator of publicness, our limited objective is determining whether it yields a distinction as useful or more useful than the traditional dichotomous ownership (i.e. government-industry) distinction.

The R&D Product Measure

As a proxy for market influence, the physical and intellectual products of the laboratory are measured in terms of their imputed market orientation. An R&D product can be thought of as being aimed at a small user group, as small as a single individual or single firm, or, at the other extreme, it can be aimed at the research/technology development community as a whole. The ordinal separations employed here classify laboratories in terms of the dominant orientation of their product. Does the individual laboratory produce a product which is predominantly for limited consumption or predominantly for general consumption. Market influence is indirectly measured as the extent to which the product (whether knowledge or physical device) is appropriable. The specific categories developed for this measure are as follows:

-- Generic R&D Product: A laboratory environment with little market influence. In this case, the principal output is a

physical or intellectual product having the characteristics of a public good.

-- Balanced R&D Product: A laboratory environment with a balance of market-directed and non-market-directed R&D products. In this environment the output is neither dominantly generic nor proprietary (see below). This type of laboratory is not just mixture (since nearly all laboratories produce at least some mix of generic and proprietary products); the key term is balance.

-- Proprietary R&D Product: A laboratory environment with heavy market influence. In this case, the principal physical or intellectual output is, in an economic sense, a private good or output which is targeted for the exclusionary use by a privileged group, usually the firm.

The Classification Scheme

As illustrated in Table I, the classification scheme results in a nine cell matrix which can be used for determining the distribution of laboratories in each cell type. A name has been designated for the environmental context of organizations within each of the nine cells. In each case, the name is descriptive of the relative influence of publicness and the mix of product types. Thus, the Public Generic cell has the characteristics of the stereotypical government lab, funded almost entirely by government funding and concentrating on R&D products which have the characteristics of a public good. Public Generic laboratories are not invariably owned by the government. Independent Market

Laboratories represent the industrial stereotype, largely independent from public influence and producing R&D products geared to the market.

--TABLE I goes here--

The Organizational Population and Its Characteristics

From the universe of North American R&D labs, our study is concerned with a study population of 829 laboratories which are involved in energy related research.[5] As demonstrated in a previous study by Martin and Irvine (1983), it was decided that a focus on R&D labs working in the same broadly defined field would have some advantages for the study. The fact that the focus is on laboratories with some similar output characteristics is beneficial to a study that is interested in determining the impact of environmental context on laboratory behavior. If our study had focused on a random grouping of R&D labs, it might have proved even more difficult to separate out the effects of publicness and R&D product type from the effects of R&D substantive focus.

Since a major purpose of this study is to contrast our classification scheme with the traditional focus on ownership type, it is important to identify the ownership distribution among the focal R&D laboratories. Table II details the ownership characteristics of the 829 R&D labs engaged in energy R&D. This initial classification exercise indicated that ownership categories required modification from the simple government/private dichotomy common in both research and policy-making. In fact, one of the most compelling arguments for a concept of publicness which expands upon the simple dichotomous view of public (govern-

ment) and private (industrial) organizations is the fact that only 51 percent of the laboratories in the study population could be classified as being either government or industrial. Even limiting this analysis to the traditional ownership distinction simply is not practical in light of the fact that so many labs no longer have the simple organizational roots common before 1940.

--TABLE II goes here--

Design and Implementation of a Descriptive Survey

A brief survey instrument was developed to facilitate the classification of the focal R&D laboratories. The questionnaire was intended to gather information about the environmental context of the individual laboratories as well as information about the organizational structure and resource flows of the laboratories. The instrument was addressed to the laboratory directors. After an initial mailing, a second mailing, and a follow-up telephone call, 250 usable questionnaires were received.

An examination of the distribution of respondents according to ownership characteristics (Table III) indicates that two of the groups, cooperative and mixed, are represented in about the same proportions as in the study population. However, the industrial group is somewhat under-represented and the government group is somewhat over-represented.

--Table III goes here.--

Classification of the Study Population

A key component of this study is provided in Table IV which classifies respondents on the basis of publicness and nature of R&D product, the two taxonomic variables of principal concern. The old stereotype, that government labs produce generic R&D products while industrial labs produce proprietary ones, does not work as well as the "new stereotype." That is -- public labs (defined in terms of government receipts) are more likely to produce generic R&D products and less public laboratories are more likely to produce proprietary products. Clearly, public labs are not always government-owned. The results of the classification indicate that laboratories of each type tend to produce a range of products regardless of ownership.

--Table IV goes here.--

The data reviewed in Table V highlight the problems associated with simple ownership based classification. Considering industrially owned laboratories alone we see that only 63% of these organizations produce an R&D product that is either proprietary or strongly proprietary, in its end use. Stereotypical assumptions regarding industrially owned R&D laboratories would lead many observers to expect that all or most of the R&D products of this type of laboratory would be proprietary by nature. While less dramatic, the research product characteristics of the government owned laboratories also deviate somewhat from stereotypical assumptions. Finally, the classification of 160 labs as being neither govern-

mental nor industrial underscores the limitations of the government lab-industrial lab stereotypes.

--Table V about here--

Analysis of the similarities and differences among laboratories classified in the various environments indicates that the publicness based dimensional classification technique does capture similar organizational forms. Table VI reviews a number of characteristics for each of the cell environments. Analysis of these characteristics indicate that, as one might expect, the research objectives of the various laboratory types move from basic to applied with decreasing levels of publicness and with increasing market influence. This observation holds for all laboratory types, regardless of individual ownership characteristics. Regarding the level of governmental influence on research goals, even among those lab types with a high level of publicness, there is a decline in the level of government influence as market influence increased.

--Table VI about here.

Case Study Evaluation of Selected Laboratories

The classification matrix developed in the previous section separates R&D laboratories according to environmental influences. The results of implementing this taxonomy led us to the preliminary conclusion that variation does occur between the laboratories classified in

each cell. This level of analysis, however, offers little in the way of assessing structural/behavioral organizational differences. In order to identify these differences at the organizational level, it was necessary that several individual organizations of each lab type be studied in greater detail. Only through a close analysis of individuals from each form can it be fully determined how they are different, and just as importantly, what some of these differences tell us about our continued use of the government-industry lab stereotypes.

The Case Study Design

The objective of the field research was the identification of the organizational characteristics for each of the R&D laboratory organizational types identified. In order to acquire this information, site visits to several research facilities in each of the environmental settings were undertaken.

For eight of the nine laboratory types, three to five case studies were selected for field study. In the case of Public Multi-Market laboratories, only two facilities were available for field study out of the four laboratories classified in that cell. The rationale for the selection of three to five cases is based on the logic provided by Arnold (1970) in his discussion of dimensional sampling. An investigation of three to five cases within taxonomically based classification schemes is seen as more than sufficient for drawing initial explanatory conclusions.

Thirty-two research facilities were visited. In each case, a common interview format was followed in a meeting with the laboratory directorate.[8] The objective of the field evaluations was to collect

background information regarding: 1) laboratory history, 2) organizational structure, 3) resource flows, 4) types of research conducted, 5) planning formats, and 6) research scope. Interviews with the laboratory directorate were followed up with laboratory tours and follow-up phone calls.

Case Study Review

The analysis of organizational difference centers on the subjective assessment of first-hand data regarding a set of organizations. In the case of this assessment, the set of organizational studies is composed of 32 cases selected from among the various cells of the R&D laboratory classification scheme. The demarcation is most important as it is differences between the organizations within a cell that should be noted. For instance, what is the degree of difference between laboratories producing generic products with varying levels of publicness? Do laboratories in each of the different environmental states have an identifiable set of characteristics that are indicative of general behavior? To answer these questions, an analysis of the case studies from each cell was conducted.

The analysis of each of the 32 cases used in this study is presented elsewhere (Crow, 1985) in much greater detail, along with a written case history. Here we have summarized the major characteristics for each laboratory, according to laboratory type. In addition, a shortened case study of a single laboratory of each type is presented as a means of highlighting the organizational characteristics which typify the laboratories in each classification. The organizational names

assigned each laboratory are fictional, but are indicative of organizational type.

Public Generic Laboratories (Cell I)

Public generic laboratories are characterized by their national focus and their utilization by the government as principal actors on the national research agenda. These laboratories, whether owned by the government, operated as a government owned/contractor operated research facility, or owned by an industry and financed by the government, are quite similar in both outlook and approach. Public generic laboratories are, for the most part, stable and, as a result, have gained a level of institutional status that makes these research organizations the key elements in the government's own research program. Public generic laboratories within their various organizational settings have many of the characteristics of the stereotypical government laboratory. For purposes of illustration we will review five public generic laboratory case studies. These cases are summarized in Table VII and include:

Acme Aviation Corporate Research Center: An industrially owned corporate level research facility of a major firm.

Energy Pollution Research Laboratory: A government-owned research facility operating as a part of a major science/technology related regulatory agency.

Institute for Advanced Energy Research: A single-program government-owned/contractor operated research laboratory. This laboratory has mixed ownership status and is operated for a government agency by a university.

Laser Science Center: This cooperatively owned and operated laboratory (government/university) is a single program research facility. The facility is operated as a government-owned/contractor-operated research laboratory.

The Neutron Institute: Cooperatively owned and operated, this laboratory is a part of a national research capability. A university operates this facility for the benefit of research, in general, with funding predominantly coming from proposals to the National Science Foundation.

A review of these cases indicates that there are two chief variations among the Public Generic labs. These variations include:

1) Government-owned and operated research facilities designed to support the implementation of specific policies.
2) Federalized research at various institutions that were either;
   a) ongoing and needed by the government, or
   b) needed by the government and federalized.

In both variations, the government, through its resources and processes, either actually controls the laboratory and all of its activities or permits the laboratories to operate as a part of a nongovernmental entity with government resources while pursuing the government's agenda. Regarding the second mode of operation, the government is interested in the continued delivery of the research products (knowledge, technology and personnel) which had generally been carried out by earlier laboratory forms over the long term. In each of these cases, the parent institutions, of their own volition and with their own resources, could not

have provided for the development and long-term maintenance of the laboratory while addressing a national research agenda.

The government supports each of the research facilities for its own interests. Those facilities with the highest levels of goal and structural influence from the government appear to have extreme difficulty in developing a high level of scientific expertise. The Energy Pollution Research Laboratory illustrates this point. In this case, the scientific program was not established outside of the government and then nationalized. On the contrary, the laboratory program was established to mirror the national policy objectives of the parent agency. Because of this fact, the laboratory itself never developed a core scientific capability. As could be expected, the parent experienced policy change quite often and, as a result, the focus of the research personnel changed in concert. Thus, rather than following the lead of scientific discovery, the laboratory staff attempts to search for technical alternatives to scientifically based policies. In this instance, policy is pushing the laboratories.

In the cases of the Acme Aviation Corporate Research Center, Institute for Advanced Energy Research, Laser Science Center and the Neutron Institute, the same type of interaction exists, but in two directions rather than one. To varying degrees, these laboratories push policy by providing new alternatives that were previously unavailable. For instance, the Acme Aviation Corporate Research Center, al*hough owned by an industrial organization, provides a mechanism for the government to induce one of its prime contractors to produce more advanced, energy efficient products. These more advanced products, although

generic in nature, eventually show up in the parent corporation's sales to the government in the form of new knowledge. In the government's cost-benefit calculation, this appears to be positive investment because it results in the development of new technological alternatives from which government policy can be implemented. The other laboratories similarly produce R&D products seen as important to the national interest.

With the exception of the Energy Pollution Research Laboratory, which is owned by the government, the remaining laboratories are all highly public facilities which came into existence during the period between 1940-1965 when government R&D support expanded rapidly. Even with the variation in impetus for formation, each of the Public Generic labs demonstrated similar structural and behavioral characteristics. These characteristics are reviewed below.

1) High levels of resource publicness do not necessarily imply that the Public Generic Laboratories are totally influenced by government authority. In fact, it appears that high levels of resource publicness provide the stability necessary to maintain unique organizational arrangements over the long term, which in turn provide for substantial goal independence in the setting of research agendas.
2) Public Generic laboratories produce largely at the technological and scientific frontiers. This production is largely in the form of publications and specialized technical services.
3) The focus of Public Generic labs is uniformly towards the long range with a particularly strong orientation toward national problems.

4) Public Generic labs are generally structured according to scientific discipline rather than government program or project constraints.

5) Public Generic laboratories have demonstrated remarkable stability, relatively speaking, in funding over the long term.

6) Program planning in both institutional planning and project funding are 'routinized' cyclical processes that occur on an annual basis under the auspices of the program plan. There is little competitive proposal preparation.

This characterization is general but applies best to the non-government-owned laboratories. Some modest contrast is provided by the Energy Pollution Research Laboratory which was not 'federalized' and moved into this environment. Instead, this facility was developed from several dispersed technical units from other, government owned, R&D laboratories. A careful review of the case study indicates that this laboratory is slightly different than the others in that it is more politicized and appears to exist in an environment of very high political authority influence. Regarding organizational stability, this Laboratory also varies to some extent as it is slightly less stable than the other four cases.

The Public Generic laboratories, while uniform in many characteristics, include two sub-categories. The government owned Energy Pollution Research Laboratory has a much higher level of government influence associated with its operation. This influence goes beyond the high publicness measure and includes high levels of governmental influence in resource acquisition, life cycle, goal setting, and structural functions.

Even with this difference, however, these laboratories are consistently similar in their research orientation, focus, and planning functions.

Public Generic laboratories are nationally oriented research facilities that have a long-range research focus and planning horizon. These laboratories perceive themselves as an important part of the national technology development process and play an active role in the policy development process.

Quasi-Public Generic Laboratories (Cell II)

The dominant characteristic of quasi-public generic laboratories is their tendency to "chase" government R&D opportunities. These laboratories have elaborate research marketing and research sales capabilities which are geared toward developing research and research services that the government appears to want. While the government is a principal client, these laboratories also market their research capability to industry and others. The four case studies summarized in Table VIII and listed below illustrate well this dominant characteristic.

Magnetic Science Center: Based at a university, this laboratory is funded by both government and industry. Government funding is an important variable to the survival of the laboratory.

California Cyclotron Center: This cooperatively owned research facility has evolved over the past 15 years to the stage where it serves both industry and government. This service research is generic in nature.

Energy Research Inc.: With its heritage in industry, this laboratory has evolved to the state where its ownership status is mixed.

Financed by both government and industry, this laboratory relies heavily on government funding for survival.

Institute for Solar System Development: Growing out of the research of a single university faculty member, this laboratory is a cooperatively owned research facility which is a part of a network of facilities supporting government and industry's solar energy research efforts.

Quasi-public generic laboratories sit at the fringe of the Public Generic facilities found in the Cell I environment. They vary significantly because of the fact that with the exception of the Institute for Solar System Development, there are no real research agendas. Rather, each of these laboratories offers its research services, specialized instrumentation and specialized personnel to any interested contracting group. It is through this 'piecemeal' research contracting that these facilities develop an ad hoc type of research program.

Because these laboratories have expertise to sell, but are operated independently of the government, they experience moderate amounts of goal influence from the government. This moderate level of governmental influence is exhibited through government management of projects, selection of research goals and as in the case of Energy Research Inc. the occasional designation of research personnel by agency personnel.

In all cases, Quasi-Public Generic laboratories actively pursue the marketing of their research capability to a broad range of potential customers. A primary customer of the past has been the government. To some extent, this fact has contributed to laboratory instability. Without continuing support that the laboratories must generate from govern-

ment and other contractors, not only does the laboratory suffer personnel shocks, but laboratory infrastructure also suffers.

Quasi-Public Generic laboratories, whether located at universities or private companies are organized around a particular set of skills or services. As time progresses and the need for those particular skills or services wanes, each of these laboratories have experienced substantial change, both structurally and behaviorally. These changes have resulted in redirections or massive reductions in the laboratories' efforts.

From the case studies of this laboratory type, it is possible to conclude the following:

1) Moderate levels of publicness and a generic R&D product result in a high rate of program change when not accompanied by either a guiding research plan or substantial parent organization support.
2) Moderate levels of publicness imply that the laboratory is not considered a part of the array of public facilities and as a result, is not a part of a routinized federal budgetary process. As a result, Quasi-Public Generic laboratories have developed extensive environmental scanning capabilities as a means of securing operating funds. These environmental scanning capabilities have resulted in these laboratories primarily working toward 'following' the research needs of both the government and industry.

3) Quasi-Public Generic laboratories appear to operate best in the general mode of independent semi-autonomous principal investigators.

4) Quasi-Public Generic laboratories appear to be relatively unstable and experience large fluctuations in their funding.

5) Research products are principally directed toward the achievement frontier and occasionally the technological frontier.

6) The research scope of Quasi-Public Generic laboratories is directed toward problems which are principally regional or local in scope.

7) Long-range planning is rare among this laboratory type. In general, the operations follow the long-range research plans of others.

8) Reductions in federal support result in either program cutbacks or movement toward more locally oriented industrially supported research.

9) The elimination of federal support of these facilities would in all likelihood result in their immediate demise.

10) The research focus of Quasi-Public Generic laboratories is as broad as the market.

Quasi-Public Generic laboratories are essentially research businesses directed toward the production of generic products, predominantly for the government. In general, they do not have a self-determined, coordinated research agenda. Instead, these laboratories have loosely coordinated research thrusts in areas which the government is interested enough to support. Because of the extent of government investment in

research ideas and services of these laboratories, their level of governmental influence is relatively high.

Because Quasi-Public Generic laboratories must "sell" their research on an idea basis, these laboratories tend to follow national trends rather than set them. Because of the constant fluctuations in the research market, the stability of these laboratories is limited. This fact contributes to a sense of competitiveness that was not seen in the Public Generic laboratories.

Independent Generic Laboratories (Cell III)

The hallmark of the independent generic laboratory is diversity and independence. These laboratories operate in environments with both the lowest level of publicness and the lowest level of market influence. As a result, these laboratories are individually unique and follow their own, albiet narrow, research agenda. Independent generic laboratories are the only research laboratory type free to chart its own course, with little concern for the government or the market. As might be expected, however, these laboratories suffer from funding difficulties. Three cases highlighting these characteristics are reviewed (see Table IX) for summary), including:

Chemical Processing Institute (CPI): Directed toward the long-term research needs of a particular industry, this cooperatively owned research laboratory is operated by a university.

The Indiana Institute (II): This privately founded research facility is cooperatively operated with funds from private, industrial and government sources.

Center for Advanced Energy Physics (CAEP): Organized around the research efforts of an academic department, this laboratory is cooperatively owned.

Independent Generic laboratories are highly independent research organizations, with non-governmental base support. Generally, the base support is in the form of personnel costs and/or facilities. In each case, the base support is considered to be the means through which a laboratory will develop. At both the Chemical Processing Institute and the Indiana Institute, an articulated research agenda and an active directorate, programs have developed. In the case of the Center for Advanced Energy Physics, no organized effort has been undertaken and as a result, the laboratory, although as equally endowed from the start as either of the other cases, has not been able to reach the critical state necessary for productive research operations.

Operating from their research base, each of the Independent Generic laboratories has as a principal function the creation of an environment conducive to research. It is the intent of each laboratory to create an environment from which individual scientists/engineers can pursue their own research agendas. The pursuit of these research agendas includes the requirement that individual researchers acquire much of their own research support. The laboratories in this mode provide an organizational umbrella for these pursuits. In addition, in the case of the Chemical Processing Institute and the Indiana Institute, the laboratory provides a program focus and overall capability. In these cases, the program focus is well-planned and enables the individual researcher to

become integrated into a larger scientific group pursuing a particular problem area.

Independent Generic laboratories pursue their own research agendas and are not a part of larger federalized systems. In the cases of CPI and the Indiana Institute, the development of the laboratories was a function of a desire to produce new types of organizational forms for research. In the case of the Center for Advanced Energy Physics, the initial intent was similar, but the realization of the goal has yet to come about.

Specific conclusions regarding Independent Generic laboratories include:

1) Independent Generic laboratories were conceived and initiated outside of the realm of the federal government or specific industrial owners.
2) Independent generic laboratories operate from a base of support and attempt to pursue contract research from this base.
3) The research products of independent generic laboratories are predominantly directed toward the technological and scientific frontier.
4) The general research focus of independent generic labs is narrow, involving in general only one or two research topics.
5) Independent Generic laboratories have a long-range focus in a narrow technological area.
6) Funding for this laboratory type is relatively stable, but in all cases is less than desired and, therefore, results in an unstable environment.

7) The organizational structure of these labs is one of autonomous principal investigators.

8) Independent Generic laboratories are insulated from policy and market fluctuations.

9) Research planning is done on an annual to biannual basis.

These conclusions indicate that Independent Generic laboratories operate outside the "mainstream" of U.S. research. These laboratories are influenced minimally by the government and minimally by the market and as a result they have established research agendas keyed almost exclusively to the expertise of their staffs. These research agendas are only minimally coordinated within the laboratories themselves. These laboratories are aptly characterized as self-directed research homes for research professionals. This characterization implies that these laboratories exist in their own worlds and set their own courses.

Because of relatively lower funding levels, these laboratories, while stable, have a narrowly focused research agenda. This research is nationally oriented but unlike Public Generic laboratories, the research is limited to a narrow technological area. Work in new technological areas develops slowly as a function of increases in funding and the acquisition of new personnel. In sum, Independent Generic labs appear to be the environmental setting of an independent type of research laboratory with a national orientation in a narrow technological focus.

Public Multi-Market Laboratories (Cell IV)

As the name implies, Public Multi-Market Laboratories are government financed research facilities producing an R&D product with various levels of market influence. As a result of this variable level of

market influence, these laboratories are characterized by complex research agenda-setting and, when compared to Public Generic laboratories, an inordinate level of organizational instability. These research organizations, as summarized in Table X, appear to be in a constant state of flux. We observed only four laboratories in this environment and were able to conduct case study analysis on only the two laboratories listed below.

The State Energy Lab: This state government-owned and operated laboratory is focused toward a broad mission of natural resource related research.

The Atomic Energy Laboratory: This government-owned laboratory is operated under charter with a government corporation. The researchfacility is directed toward nuclear research.

Even with the limitation of this analysis, there are some important characteristics common to the two cases studied. Both the State Energy Lab and the Atomic Energy Laboratory operate under the general auspices of a governmental agency to deliver technology or technical services, which at least at the time of inception, could not be provided by the market. The State Energy Lab produces technical services required for state energy resource development and the Atomic Energy Laboratory produces technology in an area where the government holds monopoly rights over the field of development. In both cases, the laboratories were established to meet the special needs of the general public. These needs included both generic and proprietary research products, thus the multi-market designation.

Specific conclusions regarding Public Multi-Market laboratories include:

1) Public Multi-Market environmental conditions create, over the long term, difficult operating modes for laboratories. There are many competing goals with strong government influence.
2) Structurally, Public Multi-Market laboratories are departmental.
3) This laboratory type operates predominantly on the technological frontier.
4) Research planning among Public Multi-Market labs is biannual to annual in nature.
5) Organizationally, Public Multi-Market laboratories appear unstable; they are pushed and pulled by the government to juggle among competing goals.
6) The research scope is regional or intrafirm.
7) The research focus is short to mid-range.
8) Public Multi-Market laboratories are highly politicized. By politicized, it is implied that senior managers are quite responsive to policy shifts.

This laboratory environment appears to be a relatively harsh operating setting in terms of stability, politicization, and difficulties in goal setting. The laboratories observed in this cell exist to serve both the market and the government with all or much of their funding being received from the government. In addition to high government funding, these laboratories experience high levels of governmental influence with regard to most of their basic organizational variables. This influence appears to be exerted as a mechanism of control because

of the partial market orientation of the R&D product. Conversely, market influence dictates performance schedules and routines from these laboratories that because of the strong influence from the market and the government with all or much of their funding being received from the government. In addition to high government funding, these laboratories experience high levels of governmental influence with regard to most of their basic organizational variables. This influence appears to be exerted as a mechanism of control because of the partial market orientation of the R&D product. Conversely, market influence dictates performance schedules and routines from these laboratories that because of the strong influence from the government commonly results in organizational conflict. Public Multi-Market laboratories appear to attempt to be all things to everyone in terms of product, yet are heavily constrained by heavy governmental influence.

Quasi-Public Multi-Market Laboratories (Cell V)

High technology and big science characterize the Quasi-Public/ Multi-Market laboratory. These are the 'think tank' research laboratories which are relied on by both government and industry for new ideas and practical market applications. With independent research agendas and highly competent staffs, these laboratories are called upon to address either a wide range of national problems in the case of the larger labs or a narrow range of national problems for the smaller versions. The three cases reviewed in Table XI exemplify these characteristics. These cases include:

The Magnetic Transport Center: This government-chartered, university-operated, multi-source funded research facility serves a number of research clients. As a result, it is cooperatively owned.

General Energy Inc.: This industrially owned laboratory is totally financed through government funds as well as its own profits from government research. In addition, it acquires research support from other industrial groups.

Institute of Superconductivity: This cooperatively operated laboratory is based at a major university with research funding from a number of sources.

Quasi-Public Multi-Market laboratories are best characterized as very specialized research facilities which are designed to meet particular needs of both industry and government. The laboratories evaluated as a part of the case study process are largely autonomous in setting goals regardless of ownership and base funding from both government and industry. This goal autonomy is based on the fact that each of these research facilities has a self-determined research agenda and through the marketing of research ideas to a number of sponsors, a laboratory program is established.

General Energy Inc. is substantially larger than either the Magnetic Transport Center or the Institute of Superconductivity, yet when it is considered as a set of research divisions, there are a number of similarities. The characteristics of the two smaller laboratories are similar to the division of General Energy Inc. in that they all operate from a base support level coming from government or industry with additional funding coming from shorter term or single project

contracts. In fact, the similarities are so great that both of the smaller labs could easily be groups within the General Energy Inc. laboratory.

Each of the Quasi-Public/Multi-Market research facilities exists at the fringe of the federal array of research labs. This position places each of these facilities outside of the day-to-day policy process and as a result produces very independent thought. Government comes to these laboratories not to conduct project X or Y, but participates in the self-determined programs of these laboratories because it is of potential benefit. Quasi-Public/Multi-Marked laboratories are in the business of producing and selling self-determined research programs, not projects. This fact, although on the surface similar to the Quasi-Public Generic laboratories in Cell II, is different because of the way in which these laboratories establish their own agenda. Quasi-Public Generic Laboratories sell research projects (not programs) and services to the government to meet particular needs. Quasi-Public/ Multi-Market Laboratories, while they do some of that, have as their predominant goal either the conduct of research for the development of specific new technologies. These facilities exist to conduct comprehensive research programs towards that end, rather than a series of disjointed projects as was the case among the Quasi-Public Generic laboratories.

The Quasi-Public character of these research facilities has several effects on laboratory behavior. In the case of General Energy Inc., the intent of the laboratory is to develop new advanced energy technologies including marketable products that are to be distributed by subsidiaries of the laboratory or the parent industry. While the government may have

similar interests, it remains distant and funds General Energy Inc. to be a part of what they are doing. Similarly, the Institute of Superconductivity is in the "business of operating a research program" and if contractors want to participate that is fine, but not critical. The Magnetic Transport Center was created to address particular problems through a unique organizational arrangement not already available in the federalized system. In each case, the laboratories are an important part of their respective national research pools, but have been kept below the higher levels of governmetal influence common in Cell I for reasons of interest from both the government and the laboratories.

Quasi-Public/Multi-Market laboratories serve both industry and government through the marketing of research programs that meet national needs. These programs require substantial continuous support and independence to be successful. Each of the cases have demonstrated that long-term delivery of useful research products to both industry and government is possible without becoming a part of either system.

Specific conclusions regarding the Quasi-Public/Multi-Market laboratories include:

1) The environment is characterized by moderate levels of publicness and balanced R&D product result in laboratory operations that are independent research entities which are, while a part of the "national research resource," self-determinant in their goals and mission.
2) Quasi-Public/Multi-Market laboratories have a national focus and orientation.

3) Long-range planning and the development of research program plans are common.

4) Federal support, while important to program stability, is not essential for laboratory survival.

5) Quasi-Public/Multi-Market Laboratories consider themselves independent of the federal bureaucracy and as a result, capable of objective non-policy directed research.

6) Research is directed toward the technological and scientific frontiers.

7) Research investigators operate predominantly in the research group mode. While independent autonomous investigators do exist, such status is gained only after attaining scientific or technological eminence.

8) Laboratory planning is on an annual to semi-annual basis.

Quasi-Public/Multi-Market laboratories were the most unusuallaboratory type observed as a part of this analysis. These laboratories, at first glance, appear to have many of the same orientations of Public Generic laboratories in Cell I; they are nationally oriented facilities with research directed toward the scientific and technological frontiers. However, these laboratories are quite different. Their research agendas, while influenced by national policy, are largely self-determined. The laboratories have developed their own mechanisms for determining their research agendas. These research agendas, probably because of internal mechanisms that lead to their establishment, are financed by a diverse group of governmental and industrial sources. As a result, these laboratories are influenced by both the market and the

government in terms of authority inputs as well as the direction of the R&D product. Subsequently, the environmental setting appears relatively stable, particularly for the older laboratories.

Independent Multi-Market Laboratories (Cell VI)

Pushed by the market of the parent industry, the Independent Multi-Market Laboratory is characterized by organizational instability, frustration, and often confusion. These research organizations want to produce non-market, often basic research products, but appear to be bound by the constraints of the market orientation of their parent organizations. In simple terms, these laboratories want to have it both ways. On the one hand they want to be able to act and behave in a fashion similar to the Quasi-Public/Multi-Market laboratories, but at the same time they have an aversion to too much government financing. The four cases reviewed in Table XII illustrate this conclusion. These cases include:

Ewing Oil R&D Inc.: An industrially owned laboratory in the oil industry with both proprietary and generic R&D products.

Petro Chem Labs Inc.: An industrially owned laboratory in the petrochemicals industry with proprietary and generic R&D products.

Seattle Tech Inc.: Growing out of the collaborative action of two firms and a government agency, this facility is presently industrially owned.

Minerals Research Laboratories Inc.: An outgrowth of a consulting/research business, this laboratory serves the minerals industry as a contract research facility.

Independent Multi-Market laboratories produce both generic and proprietary research products in an environmental setting with little or no

57-279 O - 87 - 27

direct influence from the government. This lack of direct influence from the government has resulted in a set of laboratories which are heavily influenced by changes in the economy. While each of the Independent Multi-Market laboratories produce both types of R&D products, downturns in the markets of the laboratories' income sources result in movement toward proprietary research. Upturns in market conditions conversely result in movements toward generic research. Thus, this laboratory type experiences changing research objectives on a regular basis.

In each of the cases in this cell, laboratory development was initiated for the purpose of providing technical service to either an industrial sector or individual industrial firm. This does not imply, however, that these laboratory organizations are industrially owned. As the capability to provide technical services advanced through the addition of research personnel and equipment, longer-range research was typically undertaken during periods of economic prosperity. During other periods, each of the cases reviewed in this cell reverted to their original technical service roles.

Two of the laboratories (Ewing Oil R&D Inc. and Mineral Research Laboratories Inc.) have pursued governmental funding to supplement their research income during economic downturns. In both cases, the projects were of short duration and were at best temporary activities intended to maintain or develop longer-range research capabilities.

Without exception, each of the Independent Multi-Market laboratories is interested in pursuing long-range research. Without exception, the process of establishing and maintaining such an interest and

capability has not been easy. The daily technical service needs of the firm or firms served by these laboratories, and the occasional emergency situations brought on by economic downturn all interact to make the development of a long-range research effort difficult. Only Petro Chem Labs, Inc. (PCL) has succeeded in the systematic development of a long-range research function. This occurred only after careful planning and gradual growth. At the same time, a market decline in the product lines of PCL's parent corporation could, according to laboratory management, easily cause this program to be reduced.

Specific conclusions from the Independent Multi-Market case studies include:

1) Laboratories with low levels of resource publicness and a balanced R&D product are heavily influenced by market changes.
2) Independent Multi-Market Laboratories have long-range applied research goals, but are often forced as a result of economic downturns to focus solely on the achievement frontier.
3) Independent Multi-Market laboratories have an industry specific focus which is short to mid-range in orientation.
4) Laboratory structures are departmental with most of the research organization dedicated to technical service oriented research.
5) Research program planning is market directed. As a result, as the market experiences stress, the research plan is immediately rejected for an ad hoc plan.
6) Independent multi-market laboratories experience program shifts and budget reductions with some frequency, implying that their research environment is not stable.

7) The research focus of independent multi-market labs is predominantly toward the achievement frontier with some research on the technological frontier during periods of economic prosperity.

8) Federal support appears to be of little consequence to independent multi-market labs.

9) The principal investigators are generally not autonomous.

These conclusions indicate that Independent Multi-Market laboratories operate as a function of the current market conditions affecting either the parent firm or the client industry which the laboratory serves. Unlike the Independent Market laboratories in Cell IX that appear to be more stable, particularly with regard to market fluctuations, these laboratories appear to focus on technical service-related research. This does not imply that technical service research is not done in Independent Market laboratories or other laboratory types because it is the difference with this laboratory type is a matter of focus.

Largely due to the conflict between multiple R&D product goals of the laboratories and the narrow goals of the parent industries, these laboratories consistently are pulled away from their generic R&D thrusts during periods of market instability. While the rationale behind this somewhat confusing behavior remains unclear, let us suggest the following. Independent Multi-Market laboratories, like Public Multi-Market laboratories, exist in a complex and often confusing environment in which they are heavily influenced by the parent organization(s) from which they receive their funding. They are also influenced by non-market factors as a result of their desire to produce generic R&D

products. Because of this conflict, Independent Multi-Market laboratories are less stable than the similarly directed Independent Market laboratories. As a result of their unstable research environment, these laboratories are more intensely affected by market shifts which require constant redirection of effort. As a result, these laboratories have a limited research horizon and are focused on the achievement frontier.

Public Market Laboratories (Cell VII)

Public Market laboratories are government-financed industrial research institutes of the European tradition. Similar to the industrialized nations of Europe, various units of governments in the US and Canada have financed and in some cases staffed research facilities for the sole function of conducting a research program for the consumption of a specific industry or ministry. In both cases, the research results are proprietary and the research funding base is highly public. The resulting organizational conflicts are illustrated by the four cases detailed in Table XIII and listed below.

Southwest Mining Laboratory: This government-owned and operated laboratory serves both regional and national mining interests through the production of market-oriented research.

The Provincial Mining Laboratory: Owned and operated by an agency of government at the regional level, this laboratory serves as the research arm for a regionally-based, multi-firm, mining industry.

Advanced Propulsion Laboratory: Owned and operated by a governmental agency on a University campus this laboratory serves the parent agency through the production of research which is solely consumed internal to that agency.

Underwater Energy Systems Center: Cooperatively operated by a major university and a government agency, this laboratory is charged with producing a proprietary product for the agency.

Unlike the Public Generic laboratories which are funded through relatively stable program funding, Public Market laboratories are funded on a project basis. Even those laboratories operating under the general auspices of a governmental agency are funded on a project basis. This lack of base or long-term support has contributed to an unstable funding pattern in three of the four cases reviewed. In addition, the lack of stability in the general operations of the Southwest Mining Laboratory, the Provincial Mining Laboratory, and the Advanced Propulsion Laboratory can be attributed to a general lack of long-range planning or long-term commitment on the part of the laboratories themselves or on the parent organizations.

The most dominant characteristic of the Public Market laboratories is the fact that they are so easily influenced by policy and market changes. Both laboratories, the Southwest Mining Laboratory and the Provincial Mining Laboratory, which are connected with the minerals industry through the delivery of technical services to that industry, were targeted for shutdown in the early 1980s. These shutdowns were the result of changes in the target industries' markets as well as changes in the parent agencies policies in response to these market changes. In response, the Southwest Mining lab reacted politically and secured an operating budget sufficient to maintain the laboratory. The Provincial Mining Laboratory, on the other hand, totally revised its research mission from mid- to long-range research to short-range research. In

both cases, the laboratories experienced extensive reorientation of personnel and a complete rethinking of goals and objectives.

In each case, Public Market laboratories are closely affiliated with a larger governmental organization. Regardless of ownership, each of the laboratories pursues a research program which is supported in piece-meal fashion, generally from a series of proposals.

Historical analysis of the funding of these laboratories indicates that although funding is large, its growth is sporadic and subject to rapid decline. In addition, much of the funding base of these laboratories is directed toward routine technical service and support functions. The laboratories, as a part of the larger governmental research organization, are all well integrated into the policy process of the parent agency. Each of the laboratories reviewed conducts research which is mandated and selected by the parent agency. In this mode of operation, each of the laboratories responds to the changing policies of the parent agency through new research proposals. It is fair to say that each of the laboratories spends a good deal of its organizational energy in reacting to changing policies and directives while at the same time adjusting to market conditions related to the research project. An example is the Advanced Propulsion Laboratory and its pursuit of research based on direct Congressional mandate and divergent parent agency input.

Because of the strong orientation toward the production of proprietary R&D products, Public Market laboratories also experience market-related political vulnerability. The two mining laboratories, operating

as service laboratories for the regional minerals industry, became politically vulnerable during market declines. The Advanced Propulsion Lab and the Underwater Energy Systems Center, both producing proprietary products for public sector consumers also experienced certain political vulnerabilities. This is illustrated by the case of the Advanced Propulsion Laboratory. The research product marketplace for this laboratory was controlled by managers not interested in the product. As a result, both the type of research requested and the products produced were deemed inadequate. Because of this inadequacy, the laboratory was vulnerable to shutdown. In this case, however, the laboratory was able to overcome this market impact through interdiction by Congressional subcommittee.

Specific conclusions regarding Public Market laboratories include:

1) Environments with high levels of publicness and proprietary R&D products result in highly politicized laboratories with relatively unstable programs and funding.
2) Research is conducted predominantly on the achievement frontier and during periods of stability, the technological frontier.
3) Research objectives tend to be short-range.
4) Research planning in Cell VII laboratories is highly influenced by the parent agencies and their changing policies.
5) Research planning horizons are typically one year and at best three years.
6) Laboratory funding is on a project basis with project selection largely resulting from intra-agency review.

7) Public Market laboratories are, in general, highly politicized with laboratory researchers often in direct politico/technical contact with parent agency personnel and legislative personnel.

8) Public Market laboratories are in general less stable than other high publicness laboratories.

9) Public Market laboratories are generally structured in classical hierarchical arrangements designed to meet the current needs of the parent agency.

The discussion above depicts a laboratory type that is unstable, highly politicized, and subject to severe environmental conflict. In this environment are laboratories either owned or directed by the government that are attempting to produce a market-directed research product for a specific industry. Such an environment appears to be subject to conflict and unstable R&D organizations result. This instability and its effects are particularly obvious when compared with the other high publicness laboratories. Their environments are more stable and as a result there is a broader research agenda, broader focus, and an orientation toward research rather than technical service.

Public Market laboratories seem to have fallen victim to a complex environment. As a result, these organizations spend a good deal of their time reacting to political authority influences and changes. Such a reactive mode of operation results in poor moral and possibly in poor overall effectiveness.

Quasi-Public Market Laboratories (Cell VIII)

The Quasi-Public Market laboratory is a government-financed market development center. In these research organizations we see the shared financing of product development and research service activities. For a number of reasons, these laboratories rely on government financing as a means of developing products for general market consumption. The three cases reviewed in Table XIV show a tendency to produce new products for the marketplace with a substantial amount of direct government support. These cases include:

Energy Engineering Inc.: An industrially owned research laboratory that grew up as a technology spin-off from a major research university. The laboratory relies heavily on government financing, but is financed from a range of sources.

Regional Energy Research Center: This laboratory has mixed ownership status. Housed at a university, the laboratory is a government-chartered organization with funding from a number of sources.

Advanced Turbine Research Center: This industrially owned laboratory is directed toward the production of a market-oriented research product. The development of this product is funded according to stage of development by either the parent corporation or the government.

Quasi-Public Market laboratories might at first glance appear to be quite dissimilar. Of the three cases reviewed, there is a divisional laboratory of a major corporation (Advanced Turbine Research Center), a privately held high technology firm (Energy Engineering Inc.) and an industrial research and technical service institute at a university (Regional Energy Research Center). A close analysis of each of these

facilities reveals that in all cases government financing is critical to the development or delivery of a proprietary R&D product. In the case of the Advanced Turbine Research Center, the parent corporation has the potential to make a profit from the laboratory's R&D product, yet requires substantial government investment for the laboratory's operation. Likewise, Energy Engineering Inc., although a part of a privately held high technology firm, requires its entire R&D operation to be externally funded, largely by the government. Finally, the Regional Energy Research Center, although well below a critical mass level, required government funding initially and government contracts now for even short-term delivery of proprietary products for the betterment of local energy related industries.

In each of the Quasi-Public Market laboratory cases, the operations are strongly influenced by the government as well as the market. The market influence, however, is reduced as a result of the moderate levels of publicness. Each of the laboratories enjoys lower levels of organizational risk as a result of the government's financing of between 26% and 75% of the R&D effort.

Specifically, the conclusions regarding Quasi-Public Market laboratories include:

1) The environment includes moderate levels of resource publicness and a proprietary R&D product contains R&D organizations in need of substantial external R&D support for their product or service development activities.
2) Structurally organized as departments around the technology produced or technical service delivered.

3) Research is generally single technology-focused.

4) Quasi Public Market laboratories operate largely on the achievement frontier with occasional efforts on the technological frontier.

5) Research planning in Quasi-Public Market laboratories is not common and, when present, is on a no longer than annual time frame.

6) Quasi-Public Market laboratories tend toward instability. As they are at least partially funded by sources other than the parent, the laboratory must generate much of its own operating capital on at least an annual basis.

The research focus is narrow and when geographic is regional.

8) Funding processes involve competitive proposal preparation and external review.

9) Goal setting is the result of a goal concurrence effort undertaken by the laboratory. Each laboratory attempts to find external support both in the government and among the proprietary R&D product consumers. To say the least, it is a complicated process.

As producers of market-directed R&D products, Quasi-Public Market laboratories have a single output influence. Input influences, however, are more complex with 25 percent to 75 percent of the laboratories' budgets being financed by the government. With this level of government influence, these laboratories suffer from the same type of influence conflict as was observed among Public Market laboratories but to a lesser extent.

While the influence conflict experienced among these laboratories is less than in the Public Market type, the funding stability is probably almost as poor. Because these laboratories are not funded automatically by either a parent or the government, there is always a fund chasing obstacle course that must be run. While this course is substantially less difficult than experienced by Quasi-Public Generic laboratories, it does contribute to some instability among these laboratories.

The market orientation of the R&D product of these laboratories makes them subject to the fluctuations of the market. This effect, however, is much less than in the Independent Multi-Market environment. This is attributed to the increased level of publicness.

This laboratory type tends to be single technology-focused and does not have the national orientation of Public Generic and Quasi-Public/ Multi-Market laboratories. As a result, these laboratories are not major actors in the R&D policy arena. They are, however, producers of advanced products and processes for either government or private markets.

Independent Market Laboratories (Cell IX)

Independent Market laboratories are the archetypical industrial R&D laboratories. These laboratories are market-directed research facilities with the little or no influence from the government. They serve the firm(s) of which they are a part and behave in the way industrial R&D labs are generally assumed to behave -- that is, they develop proprietary products and processes with their own resources. Four examples of Independent Market laboratories are reviewed in Table XV. These laboratories include:

Power Systems Laboratory Inc.: This industrially owned energy research facility is funded largely by the parent corporation as well as the principal consumers of the firm's products.

Smith Chemical Research Laboratory: Industrially owned chemical laboratory of a major corporation.

Black Forest Energy Laboratory Inc.: Industrially owned paper and pulp laboratory serving the regional technology needs (particularly energy related research) of a major corporation.

Metalville Research Center: Industrially owned energy/materials research laboratory serving a major corporation.

Although not always owned solely by an industrial concern, these laboratories are dedicated to the conduct of research and the delivery of technical services for the benefit of a market-driven parent organization. These laboratories conduct research programs intended to enhance processes and products, as well as search for new technological alternatives during strong economic periods. In each of the laboratories reviewed, the role of the government was minimal. The extent of government influence was limited to the indirect influences resulting from procurement or regulatory policies.

In all of the cases reviewed, the laboratories served the operating units of the parent organizations first and foremost. Research was directed toward improving daily operations of facilities or assisting customers with technical problems regarding the parent organization's processes or products.

Laboratory resources were, depending on the age of the laboratory and the extent of the research tradition in the parent organization,

available for longer-range research. This research, however, was almost always directed toward new proprietary technology. Each of three laboratories which had recognized long-range research efforts (Power Systems Lab, Smith Chemical Lab and the Metalville Research Center) had unique organization and funding arrangements for these efforts. In all cases, however, they were coordinated with extensive input from the leadership hierarchy of the parent organization.

Research directed toward the needs of the operating units or customers of the parent organization were in every case strongly influenced and, in some cases, directed by the operating units and the marketing staffs. As a result, the focus of much of the research in each case was toward problems on the achievement frontier. In these cases, environmental stress in the market or in the operating units of the parent organization resulted in a shifting of laboratory focus on the problem area. While age of the laboratory appeared to reduce the impact of these environmentally induced changes, they existed in each case.

Specific conclusions regarding the Independent Market laboratories include:

1) Independent Market labs are focused largely on assisting the operating divisions of the parent organization with incremental improvements in process or product.
2) Independent Market laboratories are market-directed with much of their research directed toward serving the technical needs of individual customers, in a sense customizing the process or products of the parent organization to meet particular needs.

3) Research is directed primarily toward the achievement frontier. With age and financial stability, the laboratories do pursue, although on a small scale, longer-range applied research. The conduct of basic research was not observed.

4) Research planning for most of the activities is coordinated with the marketing and/or operating divisions of the parent organization. For the most part, these planning efforts are short-range in scope. Regarding longer- range research, parent organization leadership along with laboratory management plan on a longer research horizon for a few specific projects.

5) Structurally, Independent Market laboratories are organized to serve the needs of the parent organization through topical research divisions.

6) The research focus of these laboratories is relatively narrow as it is limited to the market arena in which the parent organization operates.

7) Organizational stability is quite high.

8) Independent Market laboratories are well integrated with the external research community.

9) External review of R&D activities is very limited.

While many of these laboratories in the questionnaire return were cooperatively rather than industrially owned, the fact remains that these laboratories exhibit the characteristics of the industrial laboratory stereotype. Research is an important function of the parent's organization plan and these laboratories have been chartered and funded to meet this need. These laboratories serve to produce new processes/

products and to meet the technical needs of clients of the parent. They are stable, well funded and do not exhibit massive changes with the market. This fact, however, is probably a function of the fact that only healthy laboratories were studied from this cell. Research among the laboratories is generally directed toward the achievement frontier, but discretionary support for 'good ideas' was also available. In general, these laboratories are archetypal of the industrial laboratory so often referred to in the technical change literature.

Summary of Case Study Findings

The case studies reviewed above indicate that there are distinctly different characteristics among the various laboratory types. For instance, comparative analysis of Public Generic and Quasi- Public Generic laboratories indicates that a reduction of publicness levels among laboratories producing a generic product leads to a reduction in stability, shorter planning horizons, and a more applied research product. While it cannot be said with certainty that a reduction in publicness levels would produce these behavioral changes, it can be hypothesized that laboratories producing generic R&D products in an environment of high publicness versus an environment of moderate publicness are more stable, focus more on long-range research, and have longer research planning horizons.

Table XVI summarizes the variation and general organizational characteristics of the various types of R&D laboratories classified. These differences are at least the partial result of the aggregate environmental impact of varying combinations of government influence

(publicness) and market influence (nature of R&D product). These differences, when analyzed as a function of the explanatory variables of the taxonomy, result in a number of conclusions regarding both the characteristics/expectations of the laboratories and the potential reasons for some of the differences.

With the assumption that laboratory organizations are a function of their environment, the classification of laboratories based on that environment can successfully separate laboratories. It is also assumed that the same variables can be used to at least partially explain the differences observed. Given these assumptions, the major differences between R&D laboratory types summarized are reviewed below.

--Table XVI about here--

Research Scope

Variation in research scope (target of research product and orientation of research program) is limited. Only Public Generic laboratories and Quasi-Public Multi-Market laboratories have a national or interfirm research scope. In each of the other environments, laboratories operate, due to a number of constraints, on a research agenda largely directed to the larger needs of the parent organization(s). By this it is implied that the effects of the environment on laboratories in the remaining seven cells precludes operationalization of a broad research scope.

Public Generic laboratories, because of their national orientation, stable funding and minimal market influences, have been able to operate

on the scientific and technological frontier. Quasi-Public/Multi-Market laboratories, on the other hand, set their own agenda and have developed national/interfirm-oriented research programs on their own. These research agendas are not set by national policy, but are determined by the laboratories themselves. This environment of balanced R&D products (directed toward both markets) and moderate publicness appears to permit sufficient stability for this type of laboratory. This laboratory type, while not dominantly influenced by the government or the market, is able to maintain a self-identity and determine its own research scope.

Laboratories in each of the remaining seven cells have a somewhat narrower scope of research, as prescribed by the environmental setting. For instance, the research scope of the Quasi-Public Generic laboratories is substantially narrower than the Public-Generic laboratories, even though they both produce a generic research product. The reason for this narrowing in research scope in the Quasi-Public Generic laboratories is a function of the fact that these laboratories have insufficient recurring resource levels to insure stability over the long term. As a result, these laboratories follow federal funding patterns. This process reduces research scope because individual grant or contract awards are generally of a non-national/interfirm nature. Since these are what is pursued, these laboratories are prevented from operating with a national research scope.

Type of Technical Change

Both Public Generic and Quasi-Public/Multi-Market laboratories pursue self-determined research programs. As a result, they are less directed toward local/neutral (evolutionary) type changes.[7] While the

high publicness level experienced by Public Generic laboratories precludes total independence, it is important to note that these laboratories were, for the most part, federalized because of their independent ongoing research programs. The government desired a movement away from the changeable technical focus approach found in most industries. The desire was for discontinuous (evolutionary) change.

Laboratories in the remaining cells are prescribed by their environment to focus on advancing knowledge only in a linear fashion (local-neutral technical change). In Independent Multi-Market laboratories, this environmental constraint is best illustrated. The fact that they rely almost totally on parent organization funding means that first and foremost their research is directed toward linear improvement of existing products/processes. During those periods when nonlinear technical alternatives can be pursued, there is always the environmental reality of focusing on solely the parent organization's problems.

Research Frontier

The research frontier of each type of laboratory varies as a direct function of environment, but in a complicated sense. As might be expected, not all of the laboratory types producing a generic R&D product direct their research toward the scientific and technological frontier. Quasi-Public Generic laboratories direct their research efforts toward the achievement and technological frontiers because of the lack of full integration in the national array of Public Generic research laboratories. The trend between the laboratory types is hypothesized to be as follows:

1) Among the laboratory types producing a generic R&D product, high publicness implies orientation toward the scientific frontier. As market influence increases the orientation moves towards the achievement frontier.

2) With the exception of the Independent Market laboratories, R&D product as it moves toward generic implies movement away from the achievement frontier.

3) Laboratory types directed toward the achievement frontier, at least in part (Cells II, VI, VII, VIII and XI), are heavily influenced by the market. In addition, all of these laboratory types, except Independent Market laboratories, are organizationally unstable.

Research Planning

Four basic variations regarding research planning occur among the nine types of R&D laboratories identified. Public Generic laboratories are unique in that their planning horizons are generally greater than three years. The longer horizons are a function of the high levels of publicness and the fact that a generic R&D product is produced.

High publicness environments result in longer-range and more formalized planning. This tendency is intensified as the R&D product becomes more generic. Environments with lower levels of publicness plan generally only on an annual basis and even then are subject to rapid, market-induced changes in plans in the Independent Multi-Market and Quasi-Public Market laboratories.

Organizational Stability

The stability of a laboratory organization is a function of the number and extent of budget fluctuations, program change, and life cycle threats. Given this definition, stability is a function of high publicness in generic laboratories, low publicness in proprietary (market directed) laboratories and moderate publicness among those mixed market labs. In other words, laboratory stability appears to come with a clear mission and single funding source as in the cases of Public Generic and Independent Market laboratories or a self-determined course with balanced products and funding as illustrated by the Quasi-Public/Multi-Market laboratories. Another consistent difference was the program versus project-centered funding in the laboratory environments exhibiting organizational stability.

Organizational Structure

The impact of the market (R&D product) is the key determinant affecting the structure of the R&D laboratory. The more proprietary the product, the more departmental the organizational structure. Laboratory types tending toward a generic R&D product are organized around the principal investigator-centered research group. In these cases, the principal investigators have varying degrees of autonomy. Nonetheless, the research is organized around this type of research group.

Core Hypotheses

While the case study data do not permit us to make definitive conclusions about laboratory behavior, tentative findings suggest that this supplement to the traditional dichotomous distinction between public and private laboratories has some value.

The findings presented here encourage us to suggest the following core hypotheses about laboratory behavior:

1) The production of generic research in a stable environment requires high levels of publicness.
2) Moderate levels of publicness in either the production of generic or proprietary research products produce a laboratory type which is highly unstable and in some respects below an optimum threshold. This instability is the result of high levels of environmentally based goal conflict in the organization.
3) Higher levels of publicness result in longer-range planning horizons.
4) Proprietary R&D environments result in very short planning horizons and a constant need to "re-plan" research programs during their implementation due to market changes.
5) There is no relationship between pubicness and research scope to address national or interfirm needs.
6) Level of publicness is not the determinant regarding organization structure. Organization structure is largely a function of market influence. The more generic the R&D product, the more decentralized the structure and the more proprietary the product, the more centralized the structure.

R&D Policy Implications

The policy implications flowing from this study are of two types. A number of narrow-gauge propositions flow from the specific findings about laboratory behavior. But the study also raises questions about

broad, "macro-policy" issues pertaining to the allocation of resources among diverse institutional actors. We begin this section with a discussion of the narrow propositions regarding R&D laboratory behavior.

Policy Propositions

This study was designed to investigate structural and behavioral differences among R&D laboratories, but structural issues addresses are fundamental to many crucial policy questions. The case evidence presented here is not definitive and, thus, policy propositions flowing from this analysis are merely suggestive. The propositions presented below are consistent with the findings of the present study, but the propositions are, essentially, a policy research agenda.

1. Organizational stability is associated with low levels of conflict between government and market influences. If stability is prized, policy-makers are perhaps well-advised to ensure that government and market forces are not at loggerheads. Stability is not, of course, a cardinal value. Organizational change, even radical change, is sometimes beneficial. However, it is commonly observed (Miller, 1977; Gregory, 1969; Parmenter and Garber, 1971) that R&D policy that proceeds in fits and jerks with no consistent direction is a major factor in R&D failure. At least in those cases where R&D success requires long term commitment to objectives, R&D is best provided by an organization not buffeted by conflicting market and government goals. This seems to imply that heavy government financing of research directed toward proprietary products is often ill-advised. Likewise, this proposition seems to provide an explanation of at least one of the factors related to the

conflicts often observed in basic research units housed in industrial organizations and cooperatives (Twiss, 1980; Cooper, 1978).

2. The production of generic R&D products which might be used as an infratechnology base is best carried out in R&D establishments characterized by high degrees of publicness. Generic R&D labs with low publicness tend to lack the stability required for development of generic technology.

3. Strong market influence, regardless of level of publicness, reduces planning horizons and results in frequent program changes. As a result, long term research efforts are best carried out in environments with moderate to weak market influence.

4. Government incentives directed at industry affect not only the composition of R&D in particular firms, but may also result in fundamental structural change. Increased publicness (including not only direct financing but other policy interventions as well), changes the character of organizations and may be a major determinant of evolutionary processes for R&D laboratories. The implication is that tax incentives, government R&D contracts, and other such support mechanisms should be monitored not only to determine influence on directions of R&D but also with respect to possible structural impacts that may be more far-reaching and permanent. It is possible, for example, that government R&D incentives may result in the evolution of a laboratory from independent market to quasi-public market with all the attendant changes in environment and behavior.

5. Technology transfer policies should be differentiated from knowledge transfer policies and should be tailored to laboratory type.

Currently there is a growing concern in the United States that the so-called national laboratories (most of which would be classed as Public Generic laboratories) redeem the sizeable investment in public funds by technology transfer to industry (Morone and Ivins, 1982). In light of the success that the national laboratories have had in providing infratechnology and generic R&D products, a redirection toward the marketplace may be ill-advised considering the findings of conflicting market and generic goals. Knowledge transfer provides quite different benefits and entails substantially different processes than technology transfer (Technology and Information Policy Workshop, 1985). Our findings suggest transfer policies designed for implementation in public generic laboratories should focus on knowledge transfer rather than technology transfer.

Macro Policy Issues

While the findings about the publicness of R&D laboratories seem to suggest a number of managerial propositions, the entire thrust of the study calls into question one of the more significant policy assumptions of our time: that certain tasks are performed best by government, others are performed best by industry, and much of the art of policy-making is delineation of the appropriate boundaries so that tasks can be wisely allocated between government and industry.

The findings presented here can be interpreted in two very different lights. According to one perspective, the division of labor between government and industrial is badly out of kilter. Government entities are producing generic technologies, consistent with public good rationales for division of responsibilities, but they are also producing tech-

nologies clearly aimed, even during the short term, at the marketplace. Likewise, industry is not only driven by market demands and forces of competition but is also producing technologies that would seem to offer little prospect for short or even intermediate-term commercial benefit. One reaction to this state of affairs is that action must be taken to correct the mismatch of tasks and responsibilities with traditional sector-based stereotypes for allocation. A policy response based on a sector alignment assumption, that is, that organizational duties should align with the supposed performance advantages of the respective sectors, would seek to somehow get the laboratories, now obviously out of alignment back in correspondence with traditional roles.

The sector alignment assumption can be contrasted with what is termed a requisite variety assumption (Thompson, 1967). By this view, the lack of correspondence between stereotyped allocation of responsibilities and actual allocation is no cause for remedial action and may actually be beneficial. If one assumes that policy performance is accommodated by matching performance requirements to appropriate institutional structure (and that sector affiliation is not the sole factor in assessments) then the variety provided by the diverse mix of products and organizational characteristics of providers is salutary.

The findings presented here indicate that, regardless of one's policy sympathies, that the sector alignment assumption is not a plausible basis for R&D policy. Only about half of the laboratories examined here are amenable to conventional classification as governmental or industrial. Theoretically, it is possible to initiate radical changes in the institutional structure of R&D laboratories so as to reduce the

number of "mixed types" but from a practical standpoint such a policy makes little political or economic sense. If the government lab-industry lab stereotype is no longer valid, there seems little hope for policy assumptions based on classical ownership stereotypes. Whether or not a sector-alignment strategy makes sense for R&D policy, it is not, at least in its simple form, feasible.

One is not led inexorably to conclude that traditional policies based on sector distinctions are to be altogether abandoned. A revised alignment policy might be envisioned, a policy seeking to accommodate the reality of mixed type R&D labs. Such a policy strategy might, for example, seek to ensure that government laboratories focus on generic R&D products, that government laboratories eschew R&D aimed at the generation of proprietary products and short-term results, and that mixed type laboratories have a broad R&D product base and, perhaps, seek to exploit any synergisms that occur from simultaneous pursuit of applied and basic research needs. While such a revised alignment policy is not our preferred R&D policy strategy, the findings presented here and R&D effectiveness findings presented elsewhere (Crow, 1985) suggest that such a strategy has some merit. While industrial laboratories producing generic products have met with some success, government laboratories focusing primarily on proprietary R&D products have in general proved ineffective.

In our view, a policy strategy based on requisite variety assumptions is not only more realistic but also more likely to prove productive. The evolution of R&D organizations has been determined by a variety of complex and interacting factors including systematic public

policy, systematic business policy, market constraint, political competition, and virtually random organizational drift. It is not accurate to say that the various patterns of structural and institutional evolution have been invariably adaptive or even innovative. Nevertheless, this evolutionary process has produced great variety among R&D organizations and there is reason to believe that many of the new organizational forms and "hybrids" represent successful responses to changed economic, political and technological environments. If a stringent sector alignment policy strategy had been pursued, had "privatization" (Savas, 1981) criteria ruled R&D policy, it is likely that organizational structures would have been more static and that many beneficial and adaptive changes in R&D providers would not haveoccurred.

A requisite variety policy strategy does not, however, require unfettered evolution. A key component of a successful policy based on institutional and structural variety is continual monitoring, assessing and adjusting. The more or less natural evolution of R&D laboratories should be complemented by systematic attempts to assess the effectiveness of particular structural arrangements in connection with particular R&D objectives and there appears to be no good reason why such assessments should be guided by conventional stereotypes about the comparative advantages of government and industrial laboratories. If, for example, it is determined that government laboratories of a particular structural type are quite effective in producing certain market-oriented, proprietary R&D products, there is no reason to worry greatly about the failure of conventional wisdom.

Footnotes

[1]Research for this paper was supported by the Andrew W. Mellon Foundation, the Institute for Mining and Minerals Research at the University of Kentucky and by the Technology and Information Policy Program at the Maxwell School, Syracuse University.

[2]Examples of organizational and policy research which uses this stereotype as a key assumption are well reviewed in Blume (1974). Further examples of the broad use of this stereotype include; Box and Cotgrove, 1968; Muller, 1967; Avery, 1960; Brown and Shepard, 1965. Freeman (1982) illustrates the use of these stereotypes in economic related technical change theory.

[3]For elaboration of the dimensional publicness concept see Bozeman, 1984; Bozeman and Straussman, 1983; Crow, 1985; Emmert and Crow, 1985. Our paper takes the "dimensional" (as opposed to the traditional dichotomous) approach to publicness and applies the approach to the analysis of R&D labs.

[4]The R&D product variable was subjectively measured through questionnaire response on product end use and product type. To validate our assessment, participants in the study were queried as to their assessment of the validity of the categorization for their particular laboratory.

[5]To begin the process of testing the utility of this new classification scheme, a study population was drawn from the universe of more than 12,500 research and development laboratories in the United States and Canada (Catell Press, 1970; 1983; Gill, 1985; Watkins and Ruffner, 1984). The study population (N=829) represents the total group of R&D

laboratories pursuing energy or energy related research in the US and Canada.

[6]By directorate, it is implied that interviews were carried out with either the laboratory director(s) and/or member(s) of the technical management staff at the laboratory.

[7]Local/neutral type changes are those defined by Paul David as attempts to reduce the latency of existive technological alternatives. In this model, technical change is seen as a neutral process which is both evolutionary and historical. Local in this definition encompasses incremental and adaptive change only. An excellent summary of David's and other competing theories of technical change is presented by Elster (1983).

BIBLIOGRAPHY

Aldrich, H. E. Organizations and Environments. Englewood Cliffs, N.J.: Prentice-Hall, 1979.

Allen, T. J. "Communication Networks in R&D Laboratories". R&D Management, 1 (1970).

Allen, T. J. Managing the Flow of Technology. Cambridge: MIT Press, 1977.

Allison, G. T. "Public and Private Management: Are They Fundamentally Alike in all Unimportant Respects?" In Public Management: Public and Private Perspectives, J. L. Perry and K. L. Kraemer (eds.) Palo Alto, Calif.: Mayfield, 1983.

Andrews, F. M., ed. Scientific Productivity: The Effectiveness of Research Groups in Six Countries. Cambridge: New York University Press, 1979.

Argyris, C. "On the Effectiveness of Research and Development Organizations," American Scientist, vol. 56, no. 4, (Winter 1968), 334-355.

Arnold, D. O. "Dimensional Sampling: An Approach for Studying a Small Number of Cases," American Scologist, 5 (1970), 147-150.

Avery, R. W. "Enculturation in Industrial Research," IRE Transactions ,7, (1960), 20.

Baumol, W. J. and W. E. Oates, Economics, Environmental Policy and the Quality of Life. Englewood Cliffs, NJ: Prentice-Hall, 1979.

Bigoness, W. J. and W. D. Perrault. "A Conceptual Paradigm and Approach for the Study of Innovators," Academy of Management Review, Vol. 24, No. 1, (1981), 68-82.

Blume, S. S. "Behavioral Aspects of Research Management: A Review." Research Policy, 3 (1974), 40-76.

Brown, P. and C. Shepard, "The Impact of Altered Objectives, Factionalism and Organizational Change in a Research Laboratory," Social Problems, 34 (1965), 235.

Box, S. and S. Cotgrove. "The Productivity of Scientists in Industrial Research Laboratories." Sociology, vol. II, no. 2 (1968), 163-172.

Bozeman, B. L. "Dimensions of 'Publicness': An Approach to Public Organization Theory," in New Directions in Public Administration, eds. B. L. Bozeman and J. Straussman. Monterrey, Calif.: Brookes Cole, 1984.

Bozeman, B. L. and A. N. Link. Investments in Technology. New York: Praeger, 1983.

Bozeman, B. L. and J. Straussman. "Organization 'Publicness' and Resource Processes," in Organization Theory and Public Policy, eds. R. Hall and R. Quinn. Beverly Hills, Calif.: Sage Publishing, 1983.

Cattell Press. Industrial Research Laboratories of the United States. 13th edition. New York: R. R. Bowker Company, 1970.

Cattell Press. Industrial Research Laboratories of the United States, 18th edition. New York: R. R. Bowker, 1983.

Chandler, A. D. Strategy and Structure: Chapters in the History of the American Industrial Enterprise. Cambridge: MIT Press, 1962.

Cooper, M. J., "An Evaluation System for Project Selection," Research Management XXI, No. 4, 1978.

Crow, M. M. The Effect of Publicness on Organizational Performance: A Comparative Analysis of R&D Laboratories, Springfield, VA.: NTIS (PB85-216646), 1985.

Emmert, M. A. and M. M. Crow. "Interaction Among Public and Private Organizations," paper presented at the Academy of Management, San Diego, CA, August 10-13, 1985.

Evan, W. M. "Conflict and Performance in R&D Organizations: Some Preliminary Findings," in Research Program Effectiveness, pp. 471-493, eds. M. C. Yovits, D. M. Gilford, R. H. Wilcox, E. Staveley, H. D. Lerner. New York: Gordon and Breach Science Publishers, Inc., 1966.

Evan, W. M. "The Organization Set: Toward a Theory of Interorganizational Relations," in Approaches to Organizational Design, pp. 173-188, ed. James D. Thompson. Pittsburgh: University of Pittsburgh Press, 1966.

Farris, G. F. "Some Antecedents and Consequences of Scientific Performance," IEEE Transactions on Engineering Management, vol. EM-16, no. 1 (February 1969), 9-16.

Fottler, M. D. "Is Management Really Generic?" Academy of Management Review, vol. 6, no. 1 (1981), 1-12.

Freeman, C. The Economics of Industrial Innovation, 2nd Edition. Cambridge, Mass.: The MIT Press, 1982.

Fusfeld, H. I. and R. N. Langlois. Understanding R&D Productivity. New York: Pergamon Press, 1982.

57-279 O - 87 - 28

Gill, K. (ed.) Government Research Directory, 3rd edition. Detroit: Gale Research Company, 1985.

Gregory, C. "The Management of Creative Personnel," The Journal of Creative Behavior, Vol. 3, No. 4, Fall 1969, pp. 271-276.

Hyman, H. H., G. N. Levine and C. R. Wright. "Studying Expert Informants by Survey methods: A Cross-National Inquiry," Public Opinion Quarterly, vol. 31, no. 1 (1967), 9-26.

Irvine, J. and B. R. Martin. "Assessing Basic Research: Some Partial Indicators of Scientific Progress in Radio Astronomy," Research Policy, vol. 12, no. 2 (1983), 61-90.

Irvine, J. and B. R. Martin. "Assessing Basic Research: The Case of the Isaac Newton Telescope," Social Studies of Science. London: Sage, vol 13 (1983a), 49-86.

Link, A. N. "On the Efficiency of Federal R&D Spending: A Public Choice Approach." Public Choce, 31 (1977), 129-133.

Link, A. N. "The Impact of Federal Research and Development Spending on Productivity." IEEE Transactions on Engineering Management, EM-29 (1982), 166-169.

Loveless, S. Sector Status, Structure, and Performance: A Comparison of Public and Private Research Units. Unpublished Ph.D. Dissertation. Syracuse University, 1985.

McKelvey, B. Organizational Systematics. Berkeley, Calif.: University of California Press, 1982.

Marcson, S. "Government Bureaucracy and the Scientist." Paper presented at the American Sociological Association, September, 1966.

Marcson, S. "Research Environment: A Factorial Analysis of ao Government Laboratory." A paper presented to the Seventh World Congress of Sociology, Varna, Bulgaria, September, 1970.

Marcson, S. "Research Settings," in The Social Contexts of Research, eds. S. Z. Nagi and R. G. Corwin. New York: Wiley Interscience, 1972.

Marcson, S. Chapter X, "The Work Atmosphere." Scientists in Government, New Brunswick, N. J., Rutgers University, 1966.

Marcson, S. "Technical Men in Government." Science and Technology, 64 (January 1968).

Marcson, S. The Scientist in American Industry: Some Organizational Determinants in Manpower Utilization. New York: Harper and Brothers, 1960.

Marquis, D. G. and D. M. Straight. "Organizational Factors in Profit Performance," in Research Program Effectiveness, eds. M. Yovits, et al. New York: Gordon & Breach (1966), 441-459.

Miller, O. B., "How to Improve the Performance and Productivity of the Knowledge Worker," Organizational Dynamics, Vol. 5, No. 3, (Winter 1977), pp. 62-80.

Morone, J. and R. Ivins. "Problems and Opportunities in Technology Transfer from the National Laboratories to Industry," Research Management (May 1982), 35-44.

Moser, M. R. Organizational Effectiveness in Research and Development Organizations: An Application of Cameron's Methodology. Unpublished Ph.D. Dissertation, University of Massachusetts, 1983.

Muller, G. A. "Professionals in Bureaucracy: Alienation Among Industrial Scientists and Engineers," American Sociological Review, 32 (1967), 755.

Muslof, L. and M. Seidman. "The Blurred Boundaries of Public Administration," Public Administration Review, 40 (1984), 124-130.

Nelkin, D. The University and Military Research. Ithaca, New York: Cornell University Press, 1972.

Parmenter, S. M., and J. D. Garber, "Creative Scientists Rate Creativity Factors," Research Mangement, Nov, 1971.

Pashigian, B. P. "Public Ownership of Transit Facilities," Journal of Political Economy, 84 (1976), 1239-1261.

Pelz, D. C. and F. M. Andrews. Scientists in Organizations: Productive Climates for Research and Development. New York: Wiley, 1966.

Pfeffer, J. and G. R. Salancik. The External Control of Organizations. New York: Harper and Row, 1978.

Rainey, H. G., R. W. Backoff and C. H. Levine. "Comparing Public and Private Organizations," Public Administration Review, 36 (1976), 233-244.

Reppy, J. "Defense Payments for Company Financed R&D," Research Policy 6 (1977), 396-410.

Rothwell, R. and W. Zegveld. Industrial Innovation and Public Policy: Preparing for the 1980s and the 1990s. Westport, Conn.: Greenwood Press, 1981.

Sayles, L. R. and M. K. Chandler. Managing Large Systems: Organizations for the Future. New York: Harper and Row, 1971.

Schubert, G. A. The Public Interest; A Critique of the Theory of a Political Concept. Glencoe, Ill.: Free Press, 1960.

Stahl, M. J. Innovation and Productivity in Research and Development: Some Associated Individual and Organizational Variables. Unpublished Ph.D. Dissertation, 1975.

Stahl, M. J. and M. C. Koser. "Weighted Productivity in R&D: Some Associated Individual and Organizational Variables," IEEE Transactions on Engineering Management, vol. EM-25, no. 1 (February, 1978), 20-24.

Stahl, M. J. and J. A. Steger. "Improving R&D Productivity--Measuring Innovation and Productivity--A Peer Rating Approach," Research Management, 20 (January 1977), 35-38.

Stephenson, R. W., B. S. Ganty, and C. E. Erickson. "Development of Organizational Climate Inventories for Use in R&D Organizations," IEEE Transactions on Engineering Management, EM-18 (1971), 38-50.

Technology and Information Policy Workshop, Technology and Knowledge Transfer: Case Studies from Brookhaven National Laboratory, Technology and Information Policy Program, Working Paper No. 85-012, Syracuse University, 1985.

Thompson, J. D. Organizations in Action. New York: McGraw-Hill, 1967.

Toren, N. and D. Galai. "The Determinants of the Potential Effectiveness of Government Supported Industrial Research Institutes," Research Policy, 7 (1978), 362-382.

Twiss, B. Managing Technological Innovation, Second Edition, New York: Longman, 1980.

U. S. Department of Energy, Technology Transfer '83. Office of Energy Research Director of Laboratory Management, Washington D.C., DOE/ER-0192, 1984.

U. S. Department of Energy, The Stevenson-Wylder Technology Innovation Act of 1980. Report to the President and the Congress, U. S. Department of Commerce, February 1984.

Watkins, M. M. and J. A. Ruffner (eds). Research Centers Directory. 9th Edition. Detroit: Gale Research Company, 1984.

TABLE I

CLASSIFICATION SCHEME FOR R&D LABORATORIES

LEVEL OF MARKET INFLUENCE (Nature of R&D Product)	LEVEL OF GOVERNMENT INFLUENCE (Publicness)		
	HIGH	MODERATE	LOW
Generic	Cell I Environment: Public Generic	Cell II Environment: Quasi-Public Generic	Cell III Environment: Independent Generic
Balanced	Cell IV Environment: Public Multi-Market	Cell V Environment: Quasi-Public Multi-Market	Cell VI Environment: Independent Multi-Market
Proprietary	Cell VII Environment: Public Market	Cell VIII Environment: Quasi-Public Market	Cell IX Environment: Independent Market

TABLE II

CLASSIFICATION BY OWNERSHIP OF THE STUDY POPULATION

Ownership Class	Number of Units	Category Description
Industrial	258 (31.1%)	Laboratory facilities are owned by an industrial organization.
Government	74 (8.9%)	Laboratory facilities and programs are owned and operated by an agency of the government.
Cooperative	414 (49.9%)	Laboratory facilities and programs are cooperatively owned and operated by more than one organizational type.
Mixed	83 (10%)	The laboratory has portions of its' facilities and programs owned by an industrial concern or university and portions owned by a government agency.
Total	829 (100%)	

TABLE III

OWNERSHIP DISTRIBUTION OF RESPONDENTS

Ownership	Frequency	Percent	Cum Percent
Industrial	46	18.4	18.4
Govt. Agency	41	16.4	34.8
Cooperative	140	56.0	90.8
Mixed	23	9.2	100.0
Total	250	100.0	

Table IV

CLASSIFICATION OF R&D ORGANIZATIONS BY ENVIRONMENTAL INFLUENCE

LEVEL OF MARKET INFLUENCE (Nature of R & D Products)	LEVEL OF GOVERNMENTAL INFLUENCE: High	Moderate	Low	Row Total
Generic Product (Low)	Public Generic	Quasi-Public Generic	Independent Generic	
Total	121	40	6	167
Row %	72.5	24	3.6	68.2
Column %	89.6	64.5	12.5	
Total %	49.4	16.3	2.4	
Balanced Product (Moderate)	Public Multi-Market	Quasi-Public Multi-Market	Independent Multi-Market	
	4	11	10	25
	16	44	40	10.2
	3	17.7	20.8	
	1.6	4.5	4.1	
Proprietary Product (High)	Public Market	Quasi-Public Market	Independent Market	
	10	11	32	245
	18.9	20.8	60.4	100.0
	7.4	17.7	66.7	
	4.1	4.5	13.1	
Column Total%	135 55.1	62 25.3	32 19.6	

Number of missing observations = 5

TABLE V

NATURE OF R&D PRODUCT BY CLASSICAL OWNERSHIP GROUPS

	Strongly Generic	Generic	Balanced	Proprietary	Strongly Proprietary	Row Total
Industrial	1	5	11	15	14	46
	2.2	10.9	23.9	32.6	30.4	18.8
	.7	17.9	44.0	40.0	60.9	
	.4	2.0	4.5	6.1	5.7	
Government Agency	30	1	2	3	3	39
	76.9	2.6	5.1	7.7	7.7	15.9
	21.6	3.6	8.0	10.0	13.0	
	12.2	.4	.8	1.2	1.2	
Cooperative	95	19	9	11	3	137
	69.3	13.9	6.6	8.0	2.2	55.9
	68.3	67.9	36.0	36.7	13.0	
	38.8	7.8	3.7	4.5	1.2	
Mixed	13	3	3	1	3	23
	56.5	13.0	13.0	4.3	13.0	9.4
	9.4	10.7	12.0	3.3	13.0	
	5.3	1.2	1.2	.4	1.2	
Column Total	139	28	25	30	23	245
	56.7	11.4	10.2	12.2	9.4	100.0

Number of missing observations = 5

TABLE VI

LABORATORY CHARACTERISTICS BY VARIOUS LEVELS OF ENVIRONMENTAL INFLUENCE

LEVEL OF MARKET INFLUENCE (Nature of R&D Product)	LEVEL OF GOVERNMENT INFLUENCE (Publicness)		
	High	Moderate	Low
	Public Generic	Quasi-Public Generic	Independent Generic
Generic	N = 121 A = 1958 F = $2.95 GI = 2.13 Obj = 5.68	N = 40 A = 1957 F = $1.2 GI = 2.52 Obj = 5.30	N = 6 A = 1953 F = $.753 GI = 3.83 Obj = 4.4
	Public Multi-Market	Quasi-Public Multi-Market	Independent Multi-Market
Balanced	N = 4 A = 1961 F = .692 GI = 2.29 Obj = 5.75	N = 11 A = 1958 F = $2.0 GI = 3.27 Obj = 3.36	N = 10 A = 1940 F = $8.4 GI = 4.8 Obj = 2.1
	Public Market	Quasi-Public Market	Independent Market
Proprietary	N = 10 A = 1959 F = $5.66 GI = 2.5 Obj = 4.3	N = 11 A = 1957 F = $1.5 GI = 3.18 Obj = 2.18	N = 30 A = 1953 F = $6.795 GI = 4.75 Obj = 1.63

KEY:

N = Number of Observations
A = Average Year of Laboratory Startup
F = Median Annual Funding (millions of dollars)
GI = Average Level of Government Influence where 1 = dependent and 5 = independent
Obj = Research objectives of laboratory where 1 = short-range applied and 8 = long-range basic research.

TABLE VII
PUBLIC SECTOR LABORATORIES
CASE STUDY CHARACTERISTICS

	Ownership	Laboratory Funding	Total Lab Staff	Approximate Annual Budget ($ in millions)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Some Aviation Corporate Research Center (Case 12)	Industrial	1956	15	$+.3	Broad, nationally oriented research which is directed toward the search for new technological alternatives within the parent firm the operating divisions conduct product-process oriented research. In contrast, the results of this lab research are generally published in the open literature and available technical reports.	Research undertaken is directed toward new technological alternatives more than to existing technologies. The goal of the laboratory is to supply or develop the array of scientific options available for various technological applications. Examples include basic research in materials, lasers, analytical techniques and bioelectronics.	Research is undertaken almost solely on the scientific frontier. The time horizon for potential research applications is 15-20 years.	Research planning in this industrially owned lab is carried out in a multistage process with the government. R&D planning is carried out on a multi-year time frame with single year plans being persistently disrupted.	Funding for the laboratory is derived largely as a function of the parent firms sales to the government. In addition, because of the institutional need R&D planning carried out with the government lab has been var, stable.	The laboratory is a separate research facility of a parent corporation with several [illegible] which research is carried out in [illegible] based research groups which are centered around a principal research [illegible]. The laboratory structure, with its five [illegible], centered groups, is of [illegible] flow [illegible].
Energy Pollution Research Laboratory (Case 10)	Government	1970	80	$0.5	Broad, nationally oriented research directed toward the search for new technologies for [illegible] energy based pollutants	The research is directed toward the search for new technologies for [illegible] energy based pollutants.	Because the research is directed toward new alternatives for pollution control on new energy technologies rather than on the technologies themselves, it is carried out on the scientific and technological frontiers. The time horizon for research is 15-20 years.	Organizational stability from a financial perspective was too high. From a structural perspective the lab did experience instability resulting from frequent reorganization.	Planning is multi-year by lab gr with very heavy emphasis on current year planning.	Structurally, the lab is a [illegible] operated by the parent agency as a part of this network the lab is nearly [illegible] to agency R&D management [illegible]. Internally the lab is [illegible] structured around agency research topics. From a [illegible] perspective, however, the research is managed by [illegible] specific projects.
Institute for Advanced Energy Research (Case 11)	Mixed Facilities owned by a university and a government agency)	1960	5+	$15.0	The scope of research at the lab is very broad within the area of energy and materials science. There is a national orientation toward the research.	Laboratory researchers are committed to the search for new science-based technological applications. There are no specific technologies envisaged only a narrow focus for future technological application.	Research is nearly totally focused on the scientific frontier. The time, however, for potential research applications, generally 15-20 years.	Five year research planning and one year planning, programming and budgeting are institutionalized.	The lab has experienced a very stable environment for nearly +0 years. Since [illegible], there has been only minor [illegible] budget changes.	Research is carried out by [illegible] research groups. These research groups are relatively [illegible] and are based on [illegible] lead structure.
Laser Science Center (Case 9A)	Cooperative Facilities and programs are cooperatively owned and operated by a university and a government agency.	1964	60	$ 2.0	The research scope for the lab is national within a narrow research topic. To a large extent this research lab is a unique national facility and is often sited and used from an international science perspective, in this regard.	Researchers are involved only in the search for new scientific knowledge. There is no direct relationship between research and its potential technological applications.	Research is totally focused on the scientific frontier with a very long range time horizon.	Five year research planning and one year planning, programming and budgeting are institutionalized.	The lab has experienced a very stable environment for nearly +0 years.	Research is carried out by [illegible] research groups. These research groups are relatively [illegible] and are based on [illegible] lead structure.
The Neutron Institute (Case 17B)	Cooperative (Facilities and programs are cooperatively owned and operated by a university and a government agency)	1950	140	$ 7.5	This research facility is dedicated to the national research community to [illegible] energy physics and as a result has a national orientation.	Researchers are involved only in the search for new scientific knowledge. There is no direct relationship between research and the potential technological applications.	Research is totally focused on the scientific frontier with a very long range time horizon.	Five year research planning and one year planning, programming and budgeting are institutionalized.	The lab has experienced a very stable environment for nearly 10 years.	Research is carried out by [illegible] research groups. These research groups are relatively [illegible] and are based on [illegible] lead structure.

TABLE VIII
QUASI-PUBLIC GENERIC LABORATORIES
CASE STUDY CHARACTERISTICS

	Financial Ownership	Laboratory Founding	Total Lab Staff	Approx Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Magnetic Science Center (Case 506)	Cooperative (Jointly owned and operated by a university and an agency)	1969	52	$1.35	Research is directed toward a few technological applications of magnetics and is not a coordinated comprehensive program.	Research is basically evolutionary, attempting to take existing technological alternatives to magnetics and improve them. There is little searching for new alternatives.	The focus on existing techniques and their new modifications limits the research to the achievement/technological frontier. The time horizon for research is 5-10 years.	The lab receives no regular or institutional funding on a continuing basis. As a result, research planning is limited to a one year time horizon.	Because of the lack of an stable funding source, the lab has experienced a very unstable funding environment. Research funding is pieced together on a contract by contract basis.	Organized around principal investigator led research groups. The laboratory organization is a loose federation. Research groups come and go dependent on funding.
California Cyclotron Center (Case 760)	Cooperative (Jointly owned and operated by a university and an agency)	1970	35	$1.2	Lab activities are primarily directed toward the conduct of projects around the capability of a specialized research facility. The projects are not coordinated and are not directed toward any particular research agenda.	With the goal of furthering the development of existing technologies there is little searching for new technological alternatives.	The lab's goal is to assist in the development and application of technology through the utilization of the specialized research facility. In this regard, the research is directed toward improving existing technologies on the achievement and technological frontier. The time horizon for research is 5-15 years.	Research planning is carried out as a means of optimizing lab performance. This research planning was on an annual to bi-annual basis.	Since its inception, the lab has experienced instability. Funding is highly variable and the face of research changes often.	The lab staff is organized around several topical research groups. These groups are PI led and frequently change.
Energy Research Inc (Case 293)	Mixed (The facilities are partially owned by a private research company and various agencies of the government)	1966	110	$8.0	Research activities are directed toward particular energy systems and their associated efficiencies. The research is mainly focused and the projects are not coordinated.	Existing technologies are the focus of the lab. Of particular importance is improving the performance of a wide array of existing technological options. There is little searching for new alternatives.	The research of the lab is directed toward the improvement of existing technological options (achievement frontier) and on occasion alternatives available on the technological frontier. The time horizon is 3-10 years.	Research planning is quite difficult because nearly all research is carried out in response to requests for proposals.	As a result of following RFP's as the principal means of organizational funding, the lab has experienced substantial budget and program/matrix fluctuations.	The lab staff is organized around several topical research groups. These groups are PI led and frequently change
Institute for Solar System Development (Case 517)	Cooperative (Jointly owned and operated by a university and an agency)	1972	30	$1.5	The lab is directed toward research and production of specialized solar materials. The materials research is not comprehensive in nature and is focused on particular materials for limited settings.	Given that the scope of research is on a limited set of existing materials it is fair to conclude that the lab is not involved in search based technical change.	Because of the limited direct application of the materials the research focus of the lab is on the technological frontier. The time horizon is 5-10 years.	Most research is sponsored through RFP funding mechanisms, as a result research planning is difficult. There is an attempt, however, to plan a general cause for the lab on an annual or biannual basis.	Funding shifts have been dramatic and the lab has yet to find a stable funding base. It desires to have increased stability but has been elusive.	The lab staff is organized around several topical research groups. These groups are PI led and frequently change

TABLE 11
INDEPENDENT GENERIC LABORATORIES
CASE STUDY CHARACTERISTICS

	Classical Ownership	Laboratory Founding	Total Lab Staff	Approximate Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Chemical Processing Institute (Case 903)	Cooperative (Jointly owned and operated by a university and several industrial partners)	1983	10	$ .2	The lab is directed toward assisting a group of industrial firms in solving their particular chemical processing problems. The agenda does include new technology development but only within the scope of the existing needs of the research cooperative.	The technical change focus of the lab is on existing technologies. There is no significant effort which is directed toward the search for new technological options in chemical processing.	Improving the technologies on the achievement frontier and applying these on the technological frontier is the focus of this lab. The time horizon for research is 10-20 years.	Research planning is in its early stages because of the youth of the lab. At present a 2 year planning horizon is being operationalized.	The lab has come about with some difficulty and its funding stability is questionable. The lab is dependent on a few industrial cooperators and as such has a small base.	Principal investigator led research groups are the latest general approach to structure
The Ionian Institute (Case 907)	Cooperative (Jointly owned and operated by several family foundations)	1979	50	Dr.5	The lab is focused toward the application of new technological alternatives in biological energy systems. The agenda, however, is not comprehensive.	Research focuses on biological energy applications to existing energy technology arrays. As a result, there is little search induced research.	The time horizon for research is 10-20 years with efforts principally directed toward the technological frontier. Some efforts are on the scientific frontier.	Because of funding uncertainties and the loosely federated structure, research planning beyond the project level occurs only on an annual to bi-annual basis.	With less than 15% of its funding being provided by the parents the lab has experienced a high level of funding uncertainty. This uncertainty has contributed to an unstable organizational environment.	A loose federation of principal investigator led research groups
Center for Advanced Energy Physics (Case 910)	Cooperative (Jointly owned and operated by a university and several agencies)	1957	95	$8.5	Lab activities are directed toward physics applications in energy and other technologies. These efforts are directed toward the particular problems of the cooperating agencies.	There is little search induced research undertaken. Problems investigated are given to the lab within the realm of existing technologies.	Research is carried out primarily on the technological frontier and on occasion the scientific frontier. The time horizon is 10-25 years.	Annual to bi-annual planning is carried out, but its effectiveness is limited by the loose nature of the structure.	Project funding is uncertain and base funding is unstable. The result has been a high level of instability.	A loose federation of principal investigator led research groups

TABLE 3
PUBLIC MULTI-MARKET LABORATORIES
CASE STUDY CHARACTERISTICS

	Classical Ownership	Laboratory Founding	Total Lab Staff	Approx Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
The State Energy Lab (Case 6Pt)	Governmental	1890	37	$ .75	Delivery of technical support and technical information on the state energy and national resources to industrial and public interest groups.	Neutral role is played by the lab in the development of info-technology data.	Research information produced is used to assist in the application of new technological alternatives.	Funding and planning are on a biennial basis. The planning system follows the same timetable as that of the parent government agency.	Direct political intervention into the goals, objectives and particular projects of the lab have led to both financial uncertainty and program instability.	The lab is organized around typically based departments. The structure is hierarchical with all research management following the established chain of command.
The State Energy Laboratory (Case 6It)	Governmental	1944	2,300	$133.5	The development of new technologies for particular industrial settings in the area of state energy and associated technologies.	The focus of research is on the existing technology base. The search for new technological alternatives has not been undertaken recently.	With a 5-10 year time horizon, research carried out is focused on the technological frontier.	Funding and planning are on a biennial basis. The planning system follows the same timetable as that of the parent government agency.	Direct political intervention into the goals, objectives and particular projects of the lab have led to both financial uncertainty and program instability.	The lab is organized around technology based departments. The structure is hierarchical.

TABLE XI
QUASI-PUBLIC/MULTI-MARKET LABORATORIES
CASE STUDY CHARACTERISTICS

	Classical Ownership	Laboratory Founding	Total Lab Staff	Approx Annual Budget ($ in millions)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
The Magnetic Transport Center	Cooperative (Owned and operated by a University, several industries and several agencies)	1976	17	$ 0.2	The development of new advanced concepts in rapid ground transportation from a systemwide national perspective.	The focus of the lab is on the process of searching for and investigating new alternatives to the current array of technologies.	Research is focused on the technological frontier for those technologies discovered and on the scientific frontier for new alternatives. The time horizon for research is 5-20 years.	Planning is a formalized activity with substantial input from the cooperating partners. Planning is general on a 1-2 year time schedule.	Although having experienced some instability at various points in its history, the lab has entered a period of stability. This has resulted from the development of an agreed upon research agenda by the cooperating partners.	Principal investigator led research groups organized within a hierarchical structure.
General Energy Inc. (Case 0fld)	Industrial	1956	1,781	$150.0	The development of new advanced energy technologies across the spectrum of options.	The focus of the lab is on the process of searching for and investigating new alternatives to the current array of technologies.	Research is focused on developing new applications for options on the technological frontier and new permutations of various combinations of the various options. The time horizon is 5-30 years.	Research planning is a formalized corporate process within the lab itself and is on a two year time frame.	Stability in the lab has been exceptionally excellent in spite of several industrial ownership changes.	Topically structured departments with PI led research groups in areas of new emphasis.
Institute of Superconductivity (Case 611)	Cooperative (Owned and operated by a university and several industrial and government units)	1976	40	$ 1.0	To carry out a somewhat uniquely scoped effort designed to advance superconductivity based technologies.	To search for new applications and new knowledge regarding superconductivity.	Focused on both the technological and the scientific frontier the research of the lab has a 5-30 year time horizon.	Internal planning results in a research agenda which is marketed to the several interested cooperators.	Although funded by several sources, the lab is stable. This is the result of the development of a research plan rather than the pursuit of DFP's.	Principal investigator led research groups

TABLE XII
INDEPENDENT MULTI-MARKET LABORATORIES
CASE STUDY CHARACTERISTICS

	Classical Ownership	Laboratory Founding	Total Lab Staff	Approx Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Ewing Oil R&D Inc (Case 12a)	Industrial	1954	100	$ 6.1	An intrafirm research lab designed to assist in the general production of knowledge and the development of proprietary products and processes.	The focus of the lab is toward improving existing technological options rather than searching for new options.	Although the lab does have the desire to contribute to the generic technology base it can be fairly stated that all or most of its work occurs on the achievement frontier. Time horizon is 6 months or less to 2 years.	Planning is on an annual basis and is subject to frequent changes.	Market fluctuations have a strong negative effect on organizational stability.	Departmentally structured around the processes and products of the firm
Photo Chemicals Inc. (Case 3a)	Industrial	1971	101	$ 9.2	An intrafirm research lab designed to assist in the general production of knowledge and the development of proprietary products and processes.	The focus of the lab is toward improving existing technological options rather than searching for new options.	Although the lab does have the desire to contribute to the generic technology base it can be fairly stated that all or most of its work occurs on the achievement frontier. Time horizon is 6 months or less to 2 years.	Planning is on an annual basis and is subject to frequent changes.	Market fluctuations have a strong negative effect on organizational stability.	Departmentally structured around the processes and products of the firm
Seattle Toon Inc. (Case 31a)	Industrial	1940	12	$ 1.0	An intrafirm research lab designed to assist in the general production of knowledge and the development of proprietary products and processes.	The research focus of the lab is on improving the existing array of technological options available to the firm.	Although the lab does have the desire to contribute to the generic technology base it can be fairly stated that all or most of its work occurs on the achievement frontier. Time horizon is 6 months or less to 2 years.	Planning is on an annual basis and is subject to frequent changes.	Market fluctuations have a strong negative effect on organizational stability.	Departmentally structured around the processes and products of the firm
Minerals Research Laboratories Inc. (case 16b)	Mixed (Privately owned with joint operating contracts)	1961	125	$ 7.5	A research lab directed toward the immediate research problems of several firms in the energy/minerals business.	The research focus of the lab is on improving the existing array of technological options available to the firms.	Although the lab does have the desire to contribute to the generic technology base it can be fairly stated that all or most of its work occurs on the achievement frontier. Time horizon is 6 months or less to 2 years.	Planning occurs on a project basis with the individual contracting firms.	Research is totally a function of market. When the market is bad for the contracting firms, research is not carried out or cancelled.	Departmentally structured with semi-independent investigators serving as principals

TABLE 5111
PUBLIC MINERS LABORATORIES
CASE STUDY CHARACTERISTICS

	Classical Ownership	Laboratory Founding	Total Lab Staff	Normal Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Southwest Mining Laboratory (Case 5141)	Government	1962	117	$ 5.3	To deliver technical knowledge and research services to individual firms in a regionally based mining industry.	Existing technologies and their evolutionary development is the focus.	Research is limited to the achievement frontier with little or no studies on the technological frontier. Time horizon is immediate to 2 years.	Research planning follows government budget cycles only and is carried out as a means of addressing policy changes in the parent agency. Although research is planned on a two year time frame such plans are subject to frequent change.	High levels of politicization in the labs operation have led to uncertainty and instability.	Divisional research structure in technology areas.
The Provincial Mining Laboratory (Case 853)	Government	1968	135	$ 5.1	To deliver technical knowledge and research services to individual firms in a regionally based mining industry.	Existing technologies and their evolutionary development is the focus.	Research is limited to the achievement frontier with little or no studies on the technological frontier. Time horizon is immediate to 2 years.	Research planning follows government budget cycles only and is carried out as a means of addressing policy changes in the parent agency. Although research is planned on a two year time frame such plans are subject to frequent change.	High levels of politicization in the labs operation have led to uncertainty and instability.	Divisional research structure in technology areas.
Advanced Propulsion Laboratory (Case 339)	Government	1972	150	$ 6.0	To deliver technical knowledge and research services in energy materials and environmental sciences for the <u>sole</u> consumption of the parent agency.	Existing technologies and their evolutionary development is the focus.	Research is limited to the achievement frontier with little or no studies on the technological frontier. Time horizon is immediate to 2 years.	Research planning follows government budget cycles only and is carried out as a means of addressing policy changes in the parent agency. Although research is planned on a two year time frame such plans are subject to frequent change.	High levels of politicization in the labs operation have led to uncertainty and instability.	Divisional research structure in technology areas.
Underwater Energy Systems Center (Case 495)	Cooperative (Jointly owned and operated by a university and an agency)	1965	205	$16.0	The development of underwater energy systems for the <u>sole</u> consumption of the cooperating agency.	This lab has overall responsibility for the evolutionary development of this particular technology. As a part of this process, there is little research induced technical advance.	Research is limited to the achievement frontier with little or no studies on the technological frontier. Time horizon is immediate to 2 years.	Research planning follows government budget cycles only and is carried out as a means of addressing policy changes in the parent agency. Although research is planned on a two year time frame such plans are subject to frequent change.	This lab is more stable than the others of this type because it is slightly more independent.	...o.e.dna. research structure in technology areas. There are some P... based research groups, particularly when faculty from the cooperating university are involved.

TABLE XIV
QUASI-PUBLIC MARKET LABORATORIES
CASE STUDY CHARACTERISTICS

	Closeness Ownership	Laboratory Founding	Total Lab Staff	Approx Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Energy Engineering Inc. (Case 120)	Industrial	1976	25	$ 1.25	The development of proprietary energy engineering related technologies for marketing in the competitive arena.	The focus of the lab is on further development of existing technologies and not the search for new alternatives.	Research is largely limited to the achievement frontier. Although knowledge from and experience on the technological frontier is desired.	Research planning is done on an annual basis and follows general product marketing cycles. In addition plans are developed for the integration of marketing and development plans with government research support.	Funding for research comes from the government, various industries and in theory from users sales. As a result of the large number of sources there is high uncertainty. This uncertainty has resulted in a moderate level of instability.	Divisionally organized around products.
Regional Energy Research Center (Case 88)	Mixed (Owned in part by a university and in part by a government with industrial funding)	1967	15	$ .8	The development of energy related data and knowledge for individual firms in the region.	The focus of the lab is on further development of existing technologies and not the search for new alternatives.	Research is limited to the achievement frontier. Problems investigated are current technical needs in the regional energy industry.	Research planning is on a project by project basis with a very limited overall plan guiding the labs activities.	Due to the lack of an ongoing stable funding source and due to the inability to regain critical mass the lab is very unstable.	Project organized around a loose divisional structure.
Advanced Turbine Research (Case 315)	Industrial	1958	26	$ 2.0	The development of proprietary energy engineering related technologies for marketing in the competitive arena.	The focus of the lab is on further development of existing technologies and not the search for new alternatives.	Research is largely limited to the achievement frontier. Although knowledge from and experience on the technological frontier is desired.	Research planning is done on an annual basis and follows general product marketing cycles. In addition plans are developed for the integration of marketing and development plans with government research support.	Funding for research comes from the government at certain stages and the parent at other stages of the research. As a result, it is very uncertain.	Divisionally organized around products.

TABLE IV
INDEPENDENT MARKET LABORATORIES
CASE STUDY CHARACTERISTICS

	Ownership	Laboratory Founding	Total Lab Staff	Approx Annual Budget ($ in million)	Research Scope	Type of Technical Change	Research Frontier	Research Planning	Organizational Stability	Organizational Structure
Power Systems Laboratory Inc. (Case 03)	Industrial	1947	60	$00.0	The development of products and processes for marketing by the parent firm.	Basically an evolutionary research process of further development of existing technologies and the occasional search for new alternatives.	Research occurs both on the achievement frontier and the technological frontier. With the focus shifting as driven by market conditions.	Research planning is very formalized in an annual program planning and proposal development process.	The structure, funding patterns and insulation from market downturns has resulted in lab stability.	Standard product/process oriented research divisions.
Smith Chemical Research Laboratory (Case 319)	Industrial	1961	120	$ 6.6	The development of products and processes for marketing by the parent firm.	Basically an evolutionary research process of further development of existing technologies and the occasional search for new alternatives.	Research occurs both on the achievement frontier and the technological frontier. With the focus shifting as driven by market conditions.	Research planning is very formalized in an annual program planning and proposal development process.	The structure, funding patterns and insulation from market downturns has resulted in lab stability.	Standard product/process oriented research divisions.
Black Forest Energy Lab Inc (Case 150)	Industrial	1976	20	$ 1.75	The development of products and processes for marketing by the parent firm.	An evolutionary research process designed to improve current products and processes incrementally.	Research is predominantly carried out on the achievement frontier.	Research planning is very formalized in an annual program planning and proposal development process.	Relatively less stable than the other Independent Market Labs but organizationally redesigning to provide for insulation from the market.	Standard product/process oriented research divisions.
Metalville Research Center (Case 295)	Industrial	1947	400	$25.0	The development of products and processes for marketing by the parent firm.	Basically an evolutionary research process of further development of existing technologies and the occasional search for new alternatives.	Research occurs both on the achievement frontier and the technological frontier. With the focus shifting as driven by market conditions.	Research planning is very formalized in an annual program planning and proposal development process.	The structure, funding patterns and insulation from market downturns has resulted in lab stability.	Standard product/process oriented research divisions.

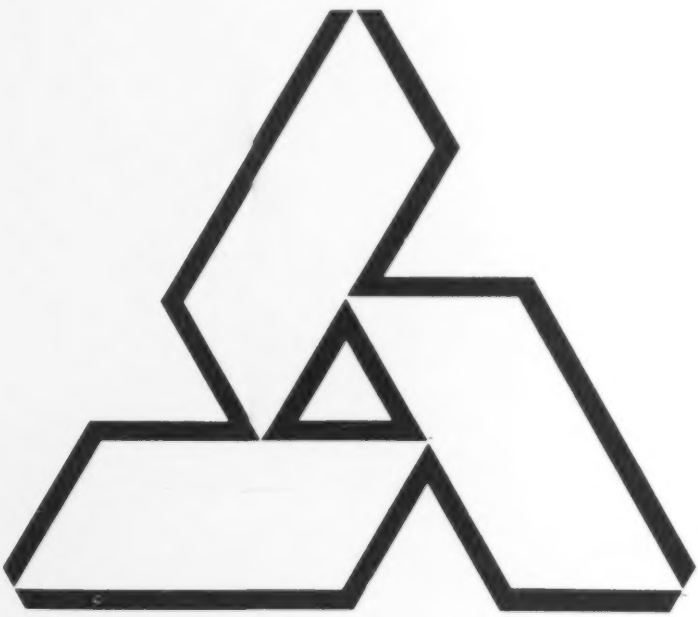
APPENDIX 3

Joint Council on
Food and
Agricultural Sciences

January 1984

Summary: Needs Assessment for the Food and Agricultural Sciences

A Report to the Congress from the Secretary of Agriculture



The Joint Council on Food and Agricultural Sciences was established in 1977 to encourage and coordinate research, extension, and higher education activities in the food and agricultural sciences. This role was strengthened in the Agriculture and Food Act of 1981, which directed the Department to improve the planning and coordination of research, extension, and higher education within the public and private sectors and to relate the federal budget process to the overall functioning of the system.

The Joint Council identified four reports which will work towards improving the overall effectiveness of the food and agricultural system.

A long-term **needs assessment** (20-30 years) for food, fiber, and forest products, including a discussion of the research, extension, and higher education requirements for meeting the identified needs. (This task was assigned to the Secretary of Agriculture in the Agriculture and Food Act of 1981. He requested the Joint Council to fulfill this responsibility). The needs assessment report was prepared and published in two separate documents. One is the *Reference Document: Needs Assessment for the Food and Agricultural Sciences* and the other is the *Summary: Needs Assessment for the Food and Agricultural Sciences*.

A **five-year plan** to reflect the coordinated goals and objectives of the research, extension, and higher education community. This report will be completed in February 1984, followed by biannual updates.

An **annual priorities report** on research, extension, and higher education, which presents the Joint Council's priorities for the next fiscal year, the required financial support, and suggested federal, state, and private-sector roles. This report will be completed by June 30 of each year.

An **annual accomplishment report** which specifies the ongoing research, extension and higher education programs and respective accomplishments, along with expectations for the future. This report will be completed by November 30 of each year.

These four reports are inter-related although each is published separately. They constitute an overall strategic planning process which will eventually provide the food and agricultural science system with a means of assessing short-term and long-term future needs and reflecting on past accomplishments. It also will provide a foundation for planning the most effective and efficient means for meeting the future demands for food, fiber, and forest products. These four reports offer a continuing mechanism by which the research, extension, and higher education programs can assess future needs.

The symbol appearing on the front cover represents the purpose of the Joint Council (i.e., to improve planning and coordination among research, extension, and higher education) and the cooperative character of the food and agricultural science system within federal, state, and private organizations.

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20250

January 30, 1984

Honorable Thomas P. O'Neill, Jr.
Speaker of the House of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

Transmitted herewith, pursuant to Section 1405 of the Agriculture and Food Act of 1981, is a "Needs Assessment for Food and Agricultural Sciences." This assessment deals with long term needs for food, fiber, and forest products and the needed supporting role of research, extension, and higher education programs.

At my request, the Joint Council on Food and Agricultural Sciences directed the preparation of the two enclosed reports:

- **Needs Assessment Reference Document** -- a 300-page report that contains 15 separate papers authored by 40 nationally prominent scientists and administrators; and

- **Needs Assessment Summary Document** -- that highlights the findings in the reference document and other recent planning reports of science and education performers in agriculture.

These reports demonstrate that the decentralized science and education system in agriculture can: 1) plan for the future in a coordinated and forward looking manner; 2) address the changing needs of farmers and consumers; and 3) be a major force in improving productivity and overall industry well being. A similar letter was sent to the President of the Senate.

Sincerely,

John Block

John R. Block
Secretary

Enclosures

Summary: Needs Assessment for the Food and Agricultural Sciences

A Report to the Congress from the Secretary of Agriculture

Contents

EXECUTIVE SUMMARY v

I. Introduction 1
A. Recent Changes Requiring a New Technological Base for Agriculture 1
B. Basis for Needs Assessment Summary 4

II. Multiple Demands Facing U.S. Agriculture as the Nation Approaches the Year 2000 and Beyond 6
A. Projected Needs for Food, Fiber, and Forest Products 6
B. Sustaining and Improving Productivity 15
C. Adequacy of the Natural Resource Base and Environmental Concerns 18
D. Providing Nutritious, Safe, and High-Quality Products 21

III. How Science and Education Can Help U.S. Agriculture Meet Changing Demands 23
A. Natural Resources 23
B. Production Agriculture 31
C. Processing, Marketing, and Distribution 39
D. Agricultural Policy—Including Adjustment Concerns 42
E. Families and Communities 45
F. International Activities 50

IV. Needs of Science and Education System To Continue Solving Problems of U.S. Agriculture 52
A. Developing Scientific Expertise in Agriculture 52
B. Biotechnology in Agriculture—New Tools for the Oldest Science 53
C. Information Systems and Communication Technology 55
D. Scientific Requirements for Maintaining Technology 57
E. Equipment and Facilities 58

V. Performers of Research, Extension, and Higher Education 61
A. Research 61
B. Extension 64
C. Higher Education 64
D. Why Public Investment? 66

References Cited 68
Appendix A—Country/Region Coverage 70
Appendix B—Source Documents 71
Appendix C—Joint Council Membership List 74

The Joint Council wishes to express its appreciation to the Needs Assessment Staff Group who prepared this summary.

Team leader: Paul F. O'Connell—FS
Other team members include: W. Joseph Lanham—ES,
Charles B. Rumburg—CSRS, Jane E. Roth—OGPS,
Sheila H. Gillette—ARS, Geri C. Richmond—OGPS.
Typing was done by Adrienne P. Baylor.
Special appreciation goes to Robert E. Buckman for his overall guidance and encouragement.

Executive Summary

The success of American agriculture is widely recognized. It has a tremendous capacity to produce and its production is highly efficient. Collectively, the food, fiber, and forest industries represent a major national asset in terms of world trade, international security, and domestic stability. Our Nation can reasonably expect an assured and reliable supply of agricultural and forestry products now and in the foreseeable future. The policy of providing public support for agricultural research and education underlies the current ability of U.S. producers to compete in world markets and to provide American consumers with high-quality and reasonably priced food, clothing, and shelter. However, past achievements will not automatically assure continued growth in productivity and industry well-being. Vast changes are underway that require a new technological base for agriculture.

- Past productivity improvements resulted from relatively low-priced land, water, fuel, chemical, and capital inputs. Since costs of these inputs have risen substantially, and will undoubtedly continue to rise, *alternate production technologies must be developed* to keep food, fiber, and forest product prices in line with past and current relative levels.

- Science has demonstrated a capability to *understand and fundamentally alter the processes of living cells.* These new abilities, along with other advances in such areas as microculture, cell fusion, regeneration of plants from single cells, and embryo recovery and transfer, are creating vast new opportunities all across the agricultural sciences.

- Advancements in computer technology enhance the computer's usefulness in analysis and transfer of information. The American agricultural system has long known that ready access to the right information at the right time is the key to success in managing inputs, production, marketing and distribution, and consumption of food, fiber, and forest products.

- There are increasing concerns about the *continued availability of the soil and water resource base.* Improved resource-saving technologies must be incorporated into our current production technologies.

- Modern agriculture depends heavily on chemicals. *The challenge is to develop chemical systems which are more highly targeted to their beneficial consequences* and which cause fewer environmental hazards.

- There is increased public awareness of the relationship between *personal well-being and diet.* Changing life styles and the increasing average age of U.S. citizens have led to questions about our nutritional needs.

• United States agriculture is becoming more *interdependent with domestic and world credit, trade, and exchange rate policies.* What national policy options can best cope with market variations (plus weather uncertainties) and also address needs of family farms, natural resource issues, and concerns of the taxpaying public?

To maintain the preeminence of United States agriculture, we must address these opportunities and issues. A critical element in meeting these challenges is *the ability of the agricultural science and education system to attract and/or train scientists and specialists with the needed skills,* e.g., molecular genetics, human nutrition, soil and water sciences, international marketing, systems analysis, and agricultural engineering.

Areas of concern include:

• Salary levels and promotion opportunities in the USDA/state system make it very difficult to retain highly qualified people in the high-tech fields.
• Graduate and undergraduate education programs are not attracting sufficient numbers of students in the critical fields.
• The average age of scientists is increasing. The formal education of many scientists is now 20 to 30 years old.

The technology development process must continue to consider *the incentives of final users.* Before new or existing techniques are adopted by an owner, manager, or consumer, many questions need answers. Will an alternative approach be more cost-effective? Can the farmer afford the additional cost when the prices of wheat, corn, or stumpage are so variable? What financial plan best fits a given farm or household? The unique aspect of agriculture is the *extension education process.* State specialists and county agents who interact regularly with the researchers also have the trust and understanding of producers and consumers. They take available research data from multiple sources and develop educational packages that consider the needs of users.

Demand-Supply Projections

At real prices approximating those of 1979-81, *effective global demand* (consumption) for agricultural and forest products is projected to expand substantially by 2000, primarily as a result of population and economic growth—about 60 percent for income-sensitive commodities such as meat, oilseeds, and processed forest products; close to 50 percent for cereal grains; and 35 to 40 percent for milk and natural fibers. By 2020, effective demand could more than double for income-sensitive commodities and could increase as much as 90 percent for cereal grains.

Output of U.S. agricultural and forest products increased nearly 40 percent in the past two decades. By 2000, production of cereal grains, oilseeds, and forest products will need to increase another 30 to 40 percent and that of other major products perhaps 20 percent. By 2020, needed production of major crops may be 70 to 100 percent above that of recent years to meet projected growth in demand from domestic and foreign markets.

For the remainder of this century and into the 21st century, the growth in demand for U.S. grains, oilseeds, and cotton will derive primarily from expansion of foreign demand. Currently (1982 figures), the United States imports about the same volume of wood products as it exports—$8.4 billion of imports versus $7.2 billion of exports. Current projections suggest little change in this position, so most growth in demand will be from domestic markets. However, the United States has a great opportunity to expand its export of forest products because: 1) world demand for paper and solid products is expected to grow, 2) many established wood-producing nations are confronted with diminished supplies; and 3) the United States has an abundant wood resource and a well-developed wood industry infrastructure. Growth in demand for meat and milk will be largely in domestic markets.

By 2000, close to 60 percent of the total consumption of U.S. cotton and soybeans and 40 percent of the consumption of cereal grains will be in foreign markets. Although projected increases in export demand are substantial—64 percent for oilseeds, 53 percent for cereals, 43 percent for cotton lint—growth rates will be well below those of the 1970's when exports of cereal grains tripled and those of oilseeds and cotton doubled. The result of these developments will be twofold: U.S. agriculture will become increasingly cash crop dependent and increasingly export dependent.

Role of Science and Education

Expanding productive capacity to permit a near doubling of output by 2020 *without major increases in real prices of food, fiber, and forest products* will require major public and private investments in science and education. New and improved technologies and better management systems will be needed to maintain and enhance resource productivity. Without continued growth in total factor productivity, there would be increased pressures on the natural resource base, increasingly serious environmental problems, and ultimately, higher real costs for food, fiber, and forest products.

- Increased production can occur without depleting the soil and water resource base if appropriate conservation practices and economic incentives can be more closely intertwined. A few possibilities include improvements in conservation tillage systems and better understanding of water stresses for both irrigated and dryland agriculture.

- The United States is rich in forests and related renewable natural resources. Intensive forest plantation management and use of alternative utilization technologies can satisfy an expanding domestic market and lead to improved world trade in forest products.

- Range resources in the United States cover enormous acreages, and have the potential for contributing much more to the economic and social well-being of the Nation. Grazing practices, range conditions, and wildlife habitats can be upgraded through improved understanding of range ecosystems.

- For both crop and animal agriculture there is a critical need to improve production efficiency. For crops, this includes enhanced genetic potential and improved yields in unfavorable environments. In animals, it involves improvements in animal feeding practices, genetic quality of stock, and animal health. Traditional technologies and new biotechnology techniques will both be explored in the pursuit of this goal.

- Post-harvest activities represent major portions of the retail cost of food, clothing, and shelter. In cooperation with the private sector, opportunities to improve transportation, processing, and packaging efficiencies need investigation.

- Policy issues needing study and clarification include: 1) the position of U.S. agriculture in the world economy; 2) effects of recent developments on size, cost, and asset distribution of farms; and 3) the role of the federal government in the domestic agricultural economy.

Future public investments in agricultural research and education should be based on more than generating technology *per se* or a simple multiplication of product output. Emphasis will be needed on the development and transfer of socially appropriate technologies that take into account not only agricultural and forest product needs but also goals concerning environmental quality; youth, family, and community development; human health and nutrition; and other sometimes competing social goals. In addition to investments in the physical and biological sciences, investments will be needed to enhance the effectiveness of institutions. The use of human development techniques and social science research can improve understanding of both human and institutional behavior.

To continue addressing the needs of U.S. agriculture, the science and education system needs to continually update and revitalize itself. It must train future scientists and managers, maintain and improve the knowledge base, have the necessary equipment and facilities, and take advantage of the new computerized information and analytical systems. It is important to remember that tomorrow's gain in scientific agriculture has its foundations in the healthiness and vitality of today's science and education community.

I. Introduction

The United States is a recognized world leader in agricultural production. This system, including related input and marketing components, generates about 20 percent of the Nation's gross national product and employs 23 percent of the U.S. labor force. Because of its diversity and efficiency, American consumers spend only 16 percent of their disposable income for food. American agricultural products are highly competitive in world markets, and their sale represents 18 percent of our total exports, contributing substantially to our balance of payments. As an industry, American agriculture has had a high rate of growth in productivity--a rate more than three times as high as that of the non-farm business sector of the economy since World War II.

Forestry also represents a significant portion of the U.S. economy. The latest comprehensive analysis shows that about $1 of every $18 of gross national product originated in some phase of timber growing, processing, and marketing. This figure does not include the important economic benefits that accrue from other forest-related uses such as hunting, fishing, camping, and grazing.

Lester C. Thurow, commenting in Newsweek magazine (1983) on the productivity of American agriculture, stated that its success "depended on more than good soil, good climate, and hard-working farmers, important as they were." He indicated that significant contribution has been made by government cooperation and funds that have been provided to the industry, especially for research and education. The federal government put major amounts of money into research, which was further developed at state experiment stations and passed along through county extension agents. "In agriculture, what started as a desperate effort to prop up a very large, sick industry in the 1930's ended as an industry that is the world's most efficient," said Thurow.

A. Recent Changes Requiring a New Technological[1] Base for Agriculture

Past achievements will not automatically assure continued growth in productivity and industry well-being. Vast changes are underway that require a new technological base for agriculture.

- Previous research focused upon obtaining high yields with little regard for controlling input levels. This occurred because of the relatively low costs for land, water, fuel, chemicals, and capital inputs. Since costs of these inputs have risen substantially, and will undoubtedly continue to rise, *alternate production technologies must be developed* to keep food, fiber, and forest product prices in line with current relative levels. In their 1983 "Recommendations" report, the National Agricultural Research and Extension Users Advisory Board made the input efficiency question their top priority.

[1]Technology refers to physical, biological, economic, and social techniques used to improve human sustenance and comfort.

• Science has demonstrated a capability to understand and fundamentally alter the processes of living cells. These new abilities, along with other advances in such areas as microculture, cell fusion, regeneration of plants from single cells, and embryo recovery and transfer, are creating vast new opportunities all across the agricultural sciences. The *tools of biotechnology* are being applied to viruses and bacteria, to insects and weeds, to plants and animals, in all stages of their life cycles from replication through aging.

• *Advancements in computer technology* enhance the computer's usefulness in analysis and transfer of information. The American agricultural system has long known that ready access to the right information at the right time is the key to success in managing inputs, production, marketing, distribution, and consumption of food, fiber, and forest products. The adoption of improved agricultural techniques continues to be limited by constraints such as: access to capital, awareness of appropriate technology, and awareness of feasible alternatives. Emerging information technologies hold the key to getting the right information to the right people at the right time and thus helping producers overcome current constraints in their operations.

• There are increasing concerns about the *continued availability of the natural resource base*. Inadequate management is damaging our soil and water resources. Improved resource-saving technologies must be incorporated into our current production technologies. What resource use patterns are consistent with sustained agricultural and forestry uses over time?

• Modern agriculture depends heavily on chemicals. All aspects of agriculture and forestry utilize chemicals in production as well as in processing and distribution. *The challenge is to develop chemical systems which are more highly targeted to their beneficial consequences and which cause fewer environmental hazards.* Some elements or compounds do not stay neatly within the narrow pathways for which they were intended, but are released to ground water, to surface water, to the air, to the soil, and to the food chain, causing both immediate and latent consequences which can be damaging.

• There is increased public awareness of the *relationship between personal well-being and diet*. Changing life styles and increasing average age of U.S. citizens have led to questions about nutritional needs. More emphasis on cereals, chicken, fish, vegetables, and fruits and suggestions that red meat, fat, and sugar make up smaller relative shares of our diet have major implications for agriculture. What are the long-term health consequences of these proposals? What are the relationships between food and mental well-being? What are the dietary needs of a population that lives longer?

• United States agriculture is becoming more *interdependent with domestic and world credit, trade, and exchange rate policies.* In combination with weather, these developments cause increased variations in prices received by U.S. farmers. What national policy options can best cope with market and weather uncertainties and also address needs of family farms, natural resource issues, and concerns of the taxpaying public?

If the preeminence of United States agriculture is to be maintained, these opportunities and issues require attention. A high priority need is *improved scientific expertise.* Currently, there are severe shortages of trained scientists to teach and conduct research in such areas as biotechnology, human nutrition, soil and water sciences, information sciences, international marketing, and agricultural engineering.

• One reason for this situation is that salary levels and promotion opportunities in the USDA/state system make it very difficult to retain highly qualified people in these high-tech fields.

• Graduate and undergraduate education programs in these fields are not attracting sufficient numbers of students to meet the need. At universities, research is inextricably linked with graduate education programs. The primary source of support is research formula funds, grants, and contracts. Agriculture must compete effectively for the limited number of students who acquire sound scientific preparation in the secondary schools.

• A third reason is the increasing average age of scientists. No matter how dedicated and hard-working such men and women may be, their output is often limited by their formal education experience, which may be 20 to 30 years old. Most of the fundamental techniques of biotechnology, systems analysis, and information science are of recent origin.

The technology development process must continue to consider *the incentives of final users.* Before new or existing techniques are adopted by an owner, manager, or consumer, many questions need answers. Will an alternative approach be more cost-effective? Can the farmer afford the additional cost when the prices of wheat, corn, or stumpage are so variable? What financial plan best fits a given farmer or household? The unique aspect of agriculture is the *extension educational process.* State specialists and county agents who interact regularly with the researchers also have the trust and understanding of producers and consumers. They take available research data from multiple sources and develop educational packages that consider the needs of users.

B. Basis for Needs Assessment Summary

In the Agriculture and Food Act of 1981, Congress reaffirmed the need for a publicly supported science and education system in agriculture (Title XIV, Section 1402). To meet future needs and challenges, the 1981 Act requires the development of a "Needs Assessment" that examines:

- the long-term needs for food, fiber, and forest products; and
- the supporting role of research, extension, and teaching programs.

This Congressional mandate provided a unique opportunity for the performers of science and education programs in agriculture to examine emerging problems and issues and communicate to both outsiders and themselves how these programs can help find solutions. Many influential people—in the Congress, in other branches of government, and in decisionmaking positions across the country—do not understand how the decentralized and pluralistic system of agricultural research and education works. This report is intended to demonstrate that dialogue does take place across and within administrative units and that the system does adjust to changing needs.

Initially, a 300-page "Reference Document" was completed—authored by 40 federal, state, and private-sector scientists, specialists, and administrators. A listing of the separate papers and authors is in Appendix B. The document highlights publicly supported research, extension, and higher education programs in agriculture. Interrelations with the private sector are often recognized. After a discussion of demand-supply projections, the document addresses problems and needed solutions in the areas of:

- natural resources—including soil, water, and air; forest, range, and wildlife; and energy.
- production agriculture—including crops and animals,
- processing, marketing, and distribution,
- agricultural policy—including adjustment concerns,
- families and communities—including human nutrition; consumer programs; and youth, family, and community development, and
- international activities.

57-279 O - 87 - 29

The report points out that in order to continue addressing the needs of U.S. agriculture, the science and education system must continually revitalize and update itself in the following areas:

- scientific expertise,
- biotechnology,
- information systems and communication technology,
- maintaining and improving the knowledge base, and
- equipment and facilities.

The "Reference Document" provided the basic material for this Summary. Other source documents included recent planning reports of federal and state performers. A list of these reports is in Appendix B.

This report obviously is not exhaustive in any sense toward covering all needs or technologies that bear on this major sector of the United States economy and its people. It does, however, serve to raise some of the major problems and opportunities envisaged for the future and presents the thoughts of some of the Nation's foremost scientists, educators, administrators, and agricultural leaders about technology and policies through which the science and education system can impact these problems.

II. Multiple Demands Facing U.S. Agriculture as the Nation Approaches the Year 2000 and Beyond

The primary function of U.S. agriculture is to provide food, fiber, and forest products for both domestic markets and an increasing share of international markets. But satisfying these product demands is only one dimension of today's agriculture. Natural resources must be properly managed so that future demands for agricultural products can also be satisfied; profitability of the farmer must be enhanced to insure a viable agriculture; efficiency of production must be improved—even more—so that all people can afford adequate food, clothing, and shelter; environmental quality concerns must be incorporated into production and processing technologies so that forests, waterways, and rural landscapes are pleasant places to live and enjoy; and the final consumers must be supplied with safe, high quality products that satisfy their changing needs.

All these demands must be addressed if the United States is to continue as a world leader in high-technology agriculture. Past improvements in land and labor productivity didn't just happen. Committed scientists and specialists were supported by producers and consumers of food, fiber, and forest products and they returned that support with improved technologies that we now take for granted. No industry can rest on its past successes. The recent experiences in the steel and auto industries should have taught us that hard lesson.

The following sections explore these needs and issues in more detail: projected needs for food, fiber, and forest products; sustaining and improving productivity; adequacy of the natural resource base and environmental concerns; and providing nutritious, safe, and high-quality products.

A. Projected Needs for Food, Fiber, and Forest Products

In recent decades the agricultural and forestry industries have become increasingly dependent upon international trade. Domestic demand for food, fiber, and timber products is expected to remain strong, but exports are expected to be the major force in determining future demand levels. World macroeconomic developments and monetary policies have had significant influence on the U.S. agricultural and forestry sectors. Thus such global variables as population growth and composition, income growth and distribution, inflation, exchange rates, interest rates, oil and other com-

modity prices, credit policies, technology, and institutional changes are important in assessing the demand for U.S. agricultural and forestry products. These factors will undoubtedly influence the future growth and development of farming and timber production patterns in the decades ahead.

Global Demand for Food and Fiber[1]

The forces and events that will determine the global demand for U.S. food and fiber through the end of the century cannot be predicted with a high degree of precision or certainty. However, the trends likely will depend on those already underway. Accordingly, the projections presented in this study rely heavily on an analysis of those factors that change slowly, follow fairly orderly patterns, and play major economic roles. A basic assumption is continued world peace, which is a precondition of trade growth.

Population growth constitutes the most important force propelling the world demand for food and fiber. For the world and for most regions, the rate of population growth is projected to slow. The world's population is, nevertheless, expected to be 39 percent larger in the year 2000 than it was in 1980. In absolute numbers, the expected 1.74 billion increase over the last two decades of the century is enormous—an average of 87 million persons per year. The importance of such an increase to food supplies is difficult to overstate.

The world produced 1.57 billion metric tons of cereals in 1980. To provide the same amount of grain per person as in 1980 to 1.74 billion additional consumers will require an additional 650 million tons (Table 2). Furthermore, the geographic incidence of population growth will continue to be extremely unequal: more than 93 percent of the growth will be in the six least developed regions, more than 25 percent in South Asia alone and 20 percent in sub-Saharan Africa. By 2000, only 19 percent of the world's people will live in the six most developed regions, a decline from 23 percent in 1980.

This study assumes rates of real *income growth* per capita that are, for most regions, somewhat lower than those experienced in the 1970's. Food consumption changes in response to income changes are estimated by means of income elasticities derived from historical experience, with appropriate allowances for recent trends.

Consumption, production, and trade are also influenced by *national policies* which are subject to gradual or, occasionally, abrupt changes. Moreover, even where policy changes have only slight effects on consumption or production, they tend to have a much greater proportional impact on trade. Therefore, changes in national policies are probably the most important element of uncertainty in any long-term trade projections.

[1]Unless otherwise indicated, the projections were based on a study conducted for USDA by Resources for the Future. A copy of their report appears in the Needs Assessment Reference Document.

The analysis and presentation of findings were done for 12 regions in the world. The regions are described in Appendix A.

Projections of World Demand: The dimensions of the changes in the per capita demand for agricultural products resulting from the projected rates of income growth are shown in Table 1. The demand for cereal grains and oilseeds includes indirect consumption in the form of livestock feed. The changes are relatively small, except for fairly rapid increases in per capita meat consumption in countries that are in the process of attaining middle-income status, e.g., Middle East, Centrally Planned Economies of Asia, and Latin America. Increases in per capita demand for grain and oilseed are projected to be less than those experienced in the 1970's.

Table 1.
World Per Capita Consumption

Products	1969-71	1978-80	Annual Change	2000	Annual Change
	kg/capita		percent	kg/capita	percent
Meat	28.3	31.8	1.3	36.8	0.70
Milk	108.0	107.1	−0.1	102.7	−0.21
Cereal Grains	334.7	361.0	0.8	371.7	0.14
Oilseeds	29.7	35.5	2.0	40.5	0.57
Fibers	5.3	5.0	−0.6	4.9	0.1

The increases in aggregate demand are, nevertheless, very large when population growth is taken into account (Table 2). World demand for meat is projected to increase by 89 million tons, or 64 percent; for milk, by 168 million tons, or 36 percent; for grains, by 722 million tons, or 46 percent; for oilseeds, by 95 million tons, or 62 percent. The largest percentage increases tend to be in the developing countries. Thus, aggregate demand for meat is projected to double or more in North Africa/Middle East, South Asia, East Asia, Centrally Planned Economies of Asia, and Latin American regions; the demand for dairy products will almost double in North Africa/Middle East, South Asia, Centrally Planned Economies of Asia, and Latin America. The increased demand for livestock products will contribute significantly to the growth of aggregate demand for cereals and oilseeds, over and above the increased demand for grains and oils for direct human consumption.

Table 2.
Anticipated Growth in Aggregate Demand
(In Millions of Metric Tons)

Region[1]	Meat			Milk			Cereals			Oilseed			Fiber		
	1979-80	2000	Increase	1979-80	2000	Increase	1979-80	2000	Increase	1979-80	2000	Increase	1979-80	2000	Increase
North Africa/Middle East	4.4	13.2	8.8	21.8	43.0	21.2	84	142	58	5	10	5	1.0	1.7	.7
Sub-Saharan	5.4	9.9	4.5	10.5	19.3	8.8	58	108	50	5	9	4	.5	.8	.3
European Community	21.9	25.4	3.5	104.1	111.0	6.9	123	133	10	32	44	12	1.3	1.2	−.1
Other Western Europe	5.0	7.3	2.3	22.0	26.3	4.3	42	58	16	6	10	4	.4	.4	—
USSR	15.8	24.3	8.5	95.9	118.3	22.4	220	306	86	12	20	8	2.9	3.6	.7
Eastern Europe	10.7	14.8	4.1	45.2	56.7	11.5	109	139	30	11	17	6	1.1	1.2	.1
South Asia	1.9	4.1	2.2	41.8	72.7	30.9	183	291	108	11	17	6	4.6	6.4	1.8
East Asia	6.5	18.7	12.2	8.9	15.1	6.2	130	224	94	9	23	14	2.3	3.5	1.2
Centrally Planned Economies of Asia	22.5	42.4	19.9	7.7	14.3	6.6	318	457	139	20	37	17	4.7	7.3	2.6
Oceania	2.3	3.2	0.9	6.3	8.8	2.5	8	16	8	—	2	2	.5	.4	−.1
Latin America	13.6	29.5	15.9	35.7	68.0	32.3	91	161	70	9	18	9	1.3	1.9	.6
North America	28.3	33.9	5.6	65.1	79.1	14.0	200	254	54	33	43	10	1.2	1.5	.2
World	**138.2**	**226.7**	**88.5** (+64%)	**464.9**	**632.5**	**167.6** (+36%)	**1568**	**2290**	**722** (+46%)	**154**	**249**	**95** (+62%)	**21.8**	**29.9**	**8.1** (+37%)

[1]Countries included in regions are shown in Appendix A.

Production and trade projections for each region of the world are available in the Needs Assessment Reference Document. They represent the best judgment of what is likely to happen under present or only slightly modified policies. They take into account considerations of comparative advantage and consumer welfare that favor increased trade, but also foreign exchange constraints and self-sufficiency and farm income objectives that may work in the opposite direction.

Source of Uncertainties: All projections of this kind are subject to uncertainties at every step in the analysis. Some examples follow:

For several decades following World War II, there was a tendency to underestimate future *population growth*, mainly because forecasters did not fully foresee the effects of progress in medicine and sanitation in reducing mortality in the developing world. More recently, the tendency has been to overestimate future population growth because of a lag in recognizing the decline in fertility rates in the wake of urbanization and industrialization, more widespread education and family planning programs, and the gradual enhancement of the social status of women. Even small revisions of population growth rates can have significant effects on the food projections.

As with population, analysts often have to work with evidence that is out of date. Therefore, they are slow to recognize changes that have already taken place, let alone changes that are likely to occur in the period of projection. Moreover, past *income growth* may have delayed effects in the future because it may take years, even a generation, for national diets to adjust to higher levels of affluence. Although an effort has been made to allow for ongoing changes, it is possible that the income elasticities for livestock products are still too low for some rapidly developing regions and too high for some affluent regions where demand is approaching satiation. For example, if per capita income growth were one-half of 1 percent higher than the base-line projections, the world demand for meat would be 8.6 percent greater and world trade in meat 42 percent greater. The effect on grain trade would not be as large (6.0 percent).

Trade patterns are highly sensitive to changes in *competitive conditions*. The United States has a substantial comparative advantage in grain and soybean production, but other countries—including Canada, Australia, Argentina, and Brazil—have become major competitors. The United States is not a significant exporter of livestock products and is not likely to become one, but it is conceivable that competitive conditions could become more favorable.

Agricultural production, consumption, and especially trade are strongly influenced by *national food and agricultural policies*. This is equally true of the centrally planned and market economies in both the developing countries and the developed world. Virtually all governments intervene extensively in agricultural markets by means of regulation, subsidization, or protection. Changes in these policies are undoubtedly the most important source of uncertainty in any long-term agricultural projections.

Implications for the United States: The United States, since the late 1960's, has pursued an agricultural policy for grains, oilseeds, and cotton that is geared to the world market. As domestic demand leveled off, production has responded primarily to trends and fluctuations in export demand. The sharp rise in export volume in the 1970's was attained by increasing acreage and yields, without lasting effects on real prices. The more moderate growth in exports projected for the next two decades is likely to come mainly from increased productivity per acre and per unit of input.

Total aggregate domestic demand for cereals is projected to increase by 18 percent, from 192.7 million metric tons in 1979-81 to 227 million tons by the year 2000. Similar increases are projected for oilseeds (22 percent), meat (19 percent) and milk (21 percent).

Net U.S. exports of cereals are projected to increase from 110 million metric tons in 1979-81 to 168 million metric tons at the end of the century. The grain export volume thus would increase by only 53 percent in 20 years, compared with the tripling experienced in the last decade. Oilseed exports are projected to increase from 33 million metric tons in 1979-81 to 54 million tons in 2000, roughly a 64 percent increase in 20 years compared with the doubling observed in the 1970's. For meat, the United States is projected to be essentially self-sufficient, with exports offsetting imports. For dairy products, net imports are projected to continue at less than 1 percent of domestic consumption (Table 3).

Table 3.
Historical and Projected Demand for Major Agricultural Products, U.S.

(In millions of metric tons)

	1969-71			1979-81			2000		
Commodity	Domestic[a]	Net Trade	Total	Domestic[a]	Net Trade	Total	Domestic[a]	Net Trade	Total
Cereals	171.0	39.0(19%)	210.0	192.7	109.6(36%)	302.3	227.0	168.2(42%)	395.3
Oilseeds[b]	20.2	17.0(46%)	37.2	31.5	33.3(51%)	64.8	38.1	53.9(59%)	92.0
Meat	21.9	.6(2%)	21.2	24.5	0 (0)	24.5	29.2	0.1(0)	29.3
Milk	53.4	-.2(-.4%)	53.2	59.0	-0.8(-1%)	58.2	71.1	-0.9(-1%)	70.2
Cotton	1.71	0.5(23%)	2.22	1.5	1.54(51%)	3.01	1.4	2.2(60%)	3.6

[a]Includes food, feed, seed, industrial use and waste
[b]Includes oilseed trade, in oilseed equivalent
Figures in parenthesis show net trade as percent of total use.

U.S. Policy: The base-line projections for the United States presuppose no major changes in policies that would significantly affect the long-term trends. It is assumed that the United States will stand ready to meet, at competitive prices, any increase in demand for its agricultural exports; and that there will be no attempt to raise the average level of export prices of these commodities above competitive levels, either unilaterally or in concert with other exporters. (This does not exclude the adoption of more effective domestic and international measures aimed at reducing year-to-year fluctuations). Import protection for dairy products and beef is assumed to continue at present levels.

Significant departures from these policies could change the trade patterns. For example, unilateral attempts by the United States to nudge export prices into higher territory could be expected to stimulate production abroad and reduce the U.S. market share. It would also adversely affect total demand, especially in low-income countries, and encourage the use of substitutes. On the other hand, policies aimed at accelerating the growth of productivity would tend to improve the competitive position of U.S. agriculture.

With no major changes in U.S. food and agriculture, monetary, and fiscal policies, U.S. export prices will continue to be volatile—very high at times and very low at times. The U.S. market share will rise when supplies are relatively tight and decline when they are relatively abundant.

Global Demand for Forestry Products

Of the 11 billion acres of forest lands that exist in the world, roughly one-third is commercially valuable and in use, one-third is unlikely to become commercially valuable, and the remaining one-third is potentially commercial but may not be in use or is inaccessible at this time.

Slightly more than half the world's forest areas are deemed accessible by existing roads, railways, waterways, or other transportation. Nearly all forests in Europe are accessible and in use, but other regions have large tracts of inaccessible forests, particularly the Amazon Basin and the northern parts of the Soviet Union and North America.

The volume of growing stock in forests in use is estimated at 5.5 trillion cubic feet—two-thirds coniferous and one-third broadleaf. Broadleaf (hardwood) species predominate, but more than half of the forest area in use is coniferous. The Soviet Union, Europe, and North America, with less than one-third of the world's population, have two-thirds of all forests, containing 90 percent of the coniferous area in use. The three areas account for two-thirds of all removals, including more than 80 percent of the world's output of industrial roundwood.

The growth of world consumption over the past 25 years for the three principal categories of forest products—lumber, wood panels, and paper—is given in the following tabulation:

	Annual Percent Growth in Consumption		
	Lumber	Panels	Paper
Developed Countries	1.1	6.2	3.8
Developing Countries	4.1	10.9	7.2
World	2.0	8.0	5.0

The United Nations Food and Agriculture Organization (FAO) projects that world demand for industrial roundwood will grow by about 2 percent per year for the next 20 years. According to FAO, consumption of paper and paperboard is expected to increase by 75 percent, wood-based panels by 55 percent, and lumber by 25 percent between 1980 and 2000. Although the absolute quantity of these projections can be questioned, they do point out prospects for growth in world forest products consumption. Net exports of logs and wood products are expected to increase by about 50 percent by century-end, with the main importers continuing to be Japan and Western Europe. The primary exporters are expected to be North America, USSR, and Southeast Asia.

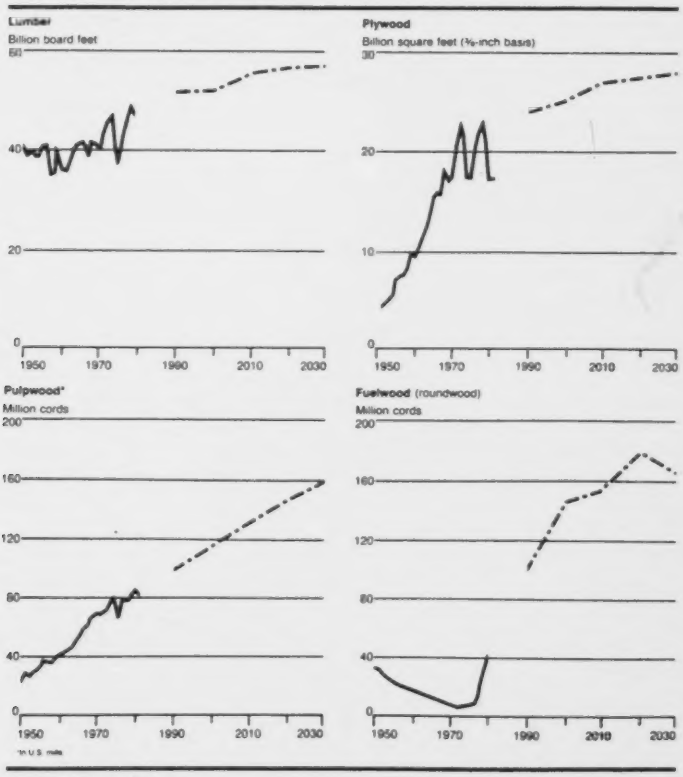
Implications for the United States:[3] Beginning with settlement and for a long time after, timber was the Nation's most important raw material. It had wide use in all types of construction and manufacturing, ranging from houses, bridges, and even road surfaces to the wagons and ships which provided the chief means of transportation. It was also the main source of fuel for domestic and industrial uses. Although over the years domestic and industrial users turned more and more to masonry, iron, steel, plastics, and other raw materials, and to fuel oil, gas, and other nonwood materials for power and heating, the demand for timber products continues, and, in total, has been rising.

Between 1950 and 1980, there was no well-defined trend in lumber consumption (fig. 1). Pulpwood use, however, increased nearly three times and plywood use more than four times. Since 1980 the recession has caused a substantial drop in consumption of lumber and plywood. The use of roundwood for fuel followed a long downward trend through the mid-1970's. Since then, consumption has increased rapidly in response to rising costs of oil and natural gas. Fuel use in 1980 was five times that of 1976.

[3]Supplement to the 1979 assessment of the Forest Rangeland Situation in the United States, U.S. Forest Service, November 1983.

As illustrated in figure 1, the longrun demands for all major timber products are projected to go up over the next five decades; as in the past, the demands for some products rise more rapidly than for others. Roundwood fuel demand rises at first and then after 2010 begins to decline, a response to projected increases in stumpage prices and fuelwood costs.

Figure 1.
Projected Timber Product Demands



Source: U.S. Forest Service

These timber product demands are met by softwood and hardwood logs. By the year 2000, softwood demand is expected to increase by 20 percent. This is in response to an expected surge in homebuilding in the last half of the 1980's as the large numbers of people born during the 1950's and 1960's seek their own place to live. Pent-up demands resulting from the recent low levels of housing construction will also contribute to the increase in housing construction.

Projected demand for hardwood timber is expected to increase 52 percent by 2000. This is largely due to growth in demands for pulpwood, fuelwood, and products such as pallets, railroad ties, and furniture.

In 1982 the United States imported about the same volume of wood products as it exported. Imports amounted to $8.4 billion; exports were $7.2 billion. During years of higher wood product consumption, the United States has been importing about twice as much as it exports. In 1979, for example, 3 billion cubic feet of timber products were imported and 1.5 billion cubic feet were exported. This trade imbalance is expected to continue into the future unless the United States becomes more competitive in world markets. According to a 1983 report by the Office of Technology Assessment:

> "The United States has an unprecedented opportunity to expand its exports of many forest products. There are three principal reasons for this: 1) world demand for paper and solid wood products is expected to grow rapidly, 2) many established wood-producing nations are confronted with diminishing wood supplies, and 3) the United States has both an abundant wood resource and a highly developed manufacturing capacity compared with most other countries."

In response to the 1980 Resource Planning Act documents of the Forest Service, Congress has recommended that the United States become a net exporter of timber products by the year 2000.

B. Sustaining and Improving Productivity[4]

"The capacity to develop and to manage technology in a manner consistent with a nation's physical and cultural endowments is the single most important variable accounting for differences in agricultural productivity among nations" (Ruttan, 1982).

[4]This section is based on an article written by W. Burt Sundquist, University of Minnesota, for "The Farm and Food System in Transition", a Cooperative Extension Project (1983).

As Ruttan's statement implies, technology policies for the agricultural system are of crucial importance if the system is to be productive. Past U.S. policies have had a substantial degree of success. For example, the cumulative effect of growth in agricultural productivity since 1940 added an estimated $112 billion to national income in 1979 alone. On the negative side, there have been recognized adverse effects (economic, environmental, and human) from some technologies. But regardless of past successes (and problems), the sources, types, and impacts of new technologies are changing and policies need to change also.

Most of the pre-20th century increase in United States farm production came from expanding the agricultural land base. This changed, however, in the decades which followed the closing of the land frontier. By the 1950's and 1960's most of the production gain came from increased productivity (an increase in the ratio of output to input) resulting from the use of science and technology. This gain came primarily from three sources: labor-saving mechanization, agricultural chemicals (particularly fertilizers, pesticides, and feed additives), and modifications in biological systems (particularly through the use of improved crop varieties and animal breeds). Much of this new technology had its origin in public research and was developed and delivered in product form through the private-sector supply industry.

But the current labor input in crop farming is small (5 percent or less of total costs for major field crops). It is somewhat higher, but declining, for animal products and for most specialty crops. Therefore, mechanization technology probably cannot greatly increase labor productivity in the future, but it can make contributions in other ways. The same applies to agricultural chemicals. Thus, *there is a crucial need to identify technologies with future productivity potential in farming and to institute policies which will help to realize this potential.*

Other factors also need to be considered in developing future policies. One consideration is that the benefits of technological change and increased productivity from mechanization, while reducing production costs for farm operators, normally mean job displacement for some farm workers. Moreover, most gains in labor productivity come at the expense of increased capital inputs. As a result, some farm operators are suffering from high capital investments which have resulted in serious cash flow problems for them. Other operators, unable or unwilling to make large capital investments, have ceased farming or now manage "low-income" farm units.

In addition, some new production technologies have generated environmental problems (such as soil erosion and toxic pollutants) which need to be considered. Thus there are important "trade-offs" to consider in developing future agricultural technologies that improve productivity.

Technology has also changed greatly in those segments of the agricultural system which lie beyond the farm gate. Since World War II this "post-harvest" or "processing

and distribution" sector has grown steadily in importance. Processing and distribution costs now account for over 70 percent of the current retail price for a consumer's market basket of farm products. The major marketing sector components of the system are farm commodity markets, transportation, processing, wholesaling, and retailing. Clearly, technology and productivity policies are important in these post-harvest components of the system too.

Productivity and Technology Defined

When a society's resources are being fully utilized, the real income status of both producers and consumers can be improved only through productivity gains—this is true both in periods of commodity surpluses and in periods of shortages. Yet one source of uncertainty about what constitutes appropriate productivity and technology policies is confusion about the meaning and use of the term "productivity." When the term productivity is used accurately, it always refers to the ratio of output to input. For example, *total productivity* is the ratio of output per unit of total input. In this measure the several inputs used in the production of goods and services—land, labor, buildings and equipment, energy, and other—are value-weighted and aggregated so that changes in output can be related to changes in total input. If such a total productivity measure is constructed carefully, it can be interpreted as a reasonably accurate depicter of technical efficiency and used to measure changes in efficiency over time.

Partial productivity measures, on the other hand, relate a selected input or group of inputs to output. Labor and land productivity measures are probably the most commonly used partial productivity measures for the agricultural system. But they have serious potential hazards: gains in labor and/or land productivities, for example, can be offset by increased capital requirements, leaving total productivity (or technical efficiency) unchanged or even reduced. Thus, total productivity is preferred to partial productivity as a measure of technical efficiency, and care should be used in interpreting the results of any partial productivity measure. *Even the total productivity measure, however, does not include such factors as environmental, social, or structural impacts of technologies.* So technology evaluation cannot be limited only to productivity measures.

The term technology is generally meant to imply a specific state of art and science which is used to transform a set of inputs (resources) into a set of outputs (goods or services). Thus the Nation's agricultural system uses a large number of technologies to produce, process, and distribute food, fiber, and forest products. Technical changes can be said to occur when the form or mix of either inputs or outputs are modified from their previous state. Thus, for example, the change from use of animal power to tractor power in production agriculture constituted a major technical change. So did the shift in forestry from hand saws to chain saws for harvesting trees. Though it is common to do so, no superiority should be automatically granted to a technology just because it possesses a single attribute such as efficiency or environmental cleanliness. Some attributes are, of course, more important than others, and technical efficiency is virtually always very important.

The significance of technical change is that it permits the substitution of knowledge for resources, or of inexpensive and abundant resources for scarce and expensive resources, or that it releases the constraints on growth imposed by inelastic resource supplies. In the process, this change generally provides some economic benefits by a cost-reducing "productivity dividend." While a change in technology can be scale-neutral, adoption of most new technologies results in increased volume capacities for the adopting firms. As a result, fewer firms are needed in the system. In addition, most recent new technologies have resulted in increased capital inputs per unit of output. And many, if not most, new technologies have been induced by cheap (undervalued) fossil-source energy inputs. Finally, the trend toward greater reliance on science-based discoveries in the development of new technologies—the so-called fusion of technology and science—has been pervasive in agriculture and is expected to continue and even to accelerate in the future.

C. Adequacy of the Natural Resource Base and Environmental Concerns

The adequacy of the U.S. natural resource base to sustain continued expansion of agricultural and forestry production came under increasingly intense scrutiny during the 1970's as a result of several events. High rates of growth in exports resulted in the return to production of some 60 million acres of cropland held in reserve under government programs in the late 1960's. With the incentive of high commodity prices in the mid-1970's, and expectations of low-cost capital, planted cropland expanded to a record high 390 million acres in 1981. The emergence of large stocks of grain in 1981 and 1982 and the withdrawal of nearly 83 million acres from production in 1983 muted but did not eliminate public concern about the adequacy and quality of the natural resource base.

At the same time, disquieting evidence of soil erosion, pollution of water supplies, overdrafts in water use in some regions, and mounting concerns regarding the environmental impacts of high usage of chemicals raised serious questions about the long-run consequences of continued high rates of growth of "high-tech" agriculture and forestry. Expectations of a slowdown in agricultural productivity growth rates were additional sources of concern.

The specter of impending crises in the availability of land and water resources to sustain growth in agricultural and forestry production evolves in part from preoccupation with the fixed physical nature of those resource supplies. But the demand for and use of those resources are determined by human choice and are powerfully influenced by social and economic criteria. Scarce resources are socially valuable resources. As a resource becomes scarcer and more socially valuable, users conserve it by substituting other resources and by adopting resource-saving technologies and management practices. Economic scarcity of a resource tends to induce an increased supply of compensating technologies. This principle of substitution is dramatically evident in the performance of U.S. agriculture and forestry in recent decades and is likely to be even more the case in the future.

Several complex, sometimes countervailing, forces will shape the competition for natural resources into the 21st century. In an increasingly interdependent society, it is to be expected that competition for natural resources will heighten. In general, the value of both water and land in nonagricultural uses exceeds their value in agriculture. Thus, where markets are operating freely and efficiently, agriculture in many locations will be in a weak competitive position for use of those resources in the 21st century. Somewhat related is the likelihood of continued erosion of the political power of agricultural interests at the national level and in many states. By the 21st century, agricultural policymakers will find it increasingly difficult to obtain or even maintain "special interest" policies for water, other resources, or agricultural commodities.

Soil Resources: A comprehensive report by Crosson and Brubaker (1982) speculates on the resource and environmental effects of U.S. agriculture to the year 2010. Anticipating greater use of herbicides to complement expanded conservation tillage, they point to gaps in knowledge about the long-term effects of even present application rates. However, they conclude that the major threat to the Nation's environment is that of soil erosion through its effects on water quality and potential productivity losses on agricultural cropland. A recent national workshop sponsored by 10 scientific societies cited "sustainable soil productivity" as their first research objective (Soil Science Society of America, 1981). Larson (1983) reports that in 1977, sheet and rill erosion exceeded "T" values (the maximum level of soil erosion that will permit a high level of crop productivity to be maintained economically and indefinitely) on some 113 million acres of cropland (27 percent of the total); on 10 percent of the cropland, erosion was more than double "T" values.

Land Resources: During the next three decades, economic pressure from nonagricultural demand on the agricultural and forest land base should be less than it has been during the past 30 years. This pressure resulted in an average annual net transfer from agriculture of some 3 million acres (875,000 acres from cropland, actual or potential) in the period 1967-75.

U.S. population growth rates are slowing. Depending upon costs of energy and social services, the dramatic migration from metropolitan to nonmetropolitan areas in the 1970's should slow. Construction rates for new airports, water and highway transport systems, dams, and reservoirs—all significant claimants upon cropland in the past—have already slowed. There are, of course, important regional and local exceptions to such generalizations. In the "sunbelt" states, for example, competition for land will intensify, posing critical choices among agricultural, urban, industrial, and other enterprises.

Water Availability: The availability and price of water, rather than land, appears to be the more critical natural resource variable for agriculture through the remainder of the century, particularly in the West. In the absence of subsidized large interbasin water transfer, it seems clear that water will be increasingly costly in the southern Great Plains with the possible result of forcing changes in water management on substantial amounts of irrigated land. Transfer of water from agriculture to meet demands in growing urban centers in the West and Southwest, whether through the expanding markets for water rights or through other institutional arrangements, could induce major adjustments in agriculture in those areas. And it seems evident that there will be no large-scale federal investment in the next decade or two in water development projects. Public policy for water in the West is moving from that of development of additional supply to that of managing the increasingly more valuable current supply.

Water Quality: Beyond these physical and economic dimensions of water resources are major problems of water quality. Groundwater contamination from agricultural as well as nonagricultural sources has become a serious problem in many parts of the country. Irrigation practices in the West have increased groundwater salinity. "Perhaps one-quarter of the lands currently under irrigation in the West are heavily dependent on nonrenewable water supplies, and the productivity of several million additional acres is threatened by rising salt levels" (Frederick, 1980). Pesticides and fertilizers may eventually seep into groundwater.

Other water quality problems—dissolved oxygen; suspended solids carrying bacteria, nutrients, and pesticides; excessive phosphoric and nitrogenic nutrients—derive in part from agricultural production practices. The 1972 Federal Water Pollution Control Act set forth ambitious goals to improve water quality. Although progress has been made—scattered evidence suggests that some of the worst pollution problems may be abating—much remains to be accomplished. Water management and water policy of the future must be concerned not only with an increasingly scarce economic resource but with externalities which affect water and environmental quality. Maintaining or improving water and environmental quality may require modification of agricultural production practices and ultimately result in higher direct costs of agricultural production (Christensen, 1983).

Energy Availability: With respect to future prices of off-farm production inputs, the future price of energy is perhaps most critical. Although the agricultural sector adjusted fairly readily to the sharp increases in petroleum and other fossil-fuel-dependent inputs such as nitrogen fertilizer in the middle and late 1970's, it did so under conditions of generally rising farm product prices. Although current expectations suggest only small increases in the real price of fossil fuel energy for the remainder of this decade and possibly to the year 2000, the tenuous, volatile international political circumstances of world petroleum supplies and prices remain a source of substantial uncertainty for much of of the U.S. economy. This suggests the importance of developing non-petroleum energy sources, energy-conserving technologies and production systems, and energy policies which provide incentives for conservation.

D. Providing Nutritious, Safe, and High-Quality Products

American consumers have access to more high-quality, moderately priced, safe food, fiber, and forest products than any other people in the world. This results from a complex but very successful interaction of private and public sectors. The research, education, and regulatory functions of governmental agencies and the technical and managerial expertise of industry form a partnership that means better food, clothing, and shelter for all.

Food: We know a great deal about human nutrient needs, but we must learn more. As new crop varieties and livestock strains are developed through improved breeding techniques, including genetic engineering, changes in the nutrient composition of food may be introduced. Improved food processing techniques to reduce costs, increase storage time, and produce new foods may also have unforeseen effects on the nutrient content of food.

The U.S. population is growing older. By the year 2000 the U.S. is expected to have over 30 million people 65 years of age and older. As many as one in five will be in that age category during the 21st century. Nutrient needs, food choices, and the ability to digest and absorb food are likely to change with age. For example, some have suggested that our older population will need more protein and calcium in their diet. Will it be best for older people to choose meat and milk to meet these needs? Would other food choices be better to increase chances of remaining in good health? Can proper nutrition delay or prevent heart disease, cancer, osteoporosis, and other diseases of old age? There are many questions needing answers.

Regulatory agencies like the Food Safety and Inspection Service (FSIS) are becoming more dependent on a technical information base to make and carry out their decisions. The problems that FSIS addresses involves questions of safety such as toxicities, residues, nitrites, and microbial contaminations and questions of quality such as appropriate food additives, ingredients, and processing and grading specifications.

Wood and Fiber: The wood and fiber industries are not as highly regulated as the food industry is, but these products must undergo several safety and quality checks before they reach the consumer. Voluntary compliance with industry-wide codes is a dominant feature of these sectors. Major buyers of lumber, cotton, and wool also have considerable impact on the type of products that are made available to the consumer. For example, public and private financial institutions specify the type of materials and construction standards for structures they finance. Publicly supported science and education programs are a major source of technical data and analysis.

The foundation on which standards are established for processing and grading cotton, wool, and wood products is government-sponsored research. The results have the credibility required to establish industry-wide compliance. A few examples of problems requiring answers now are: 1) Identifying the agent causing brown lung disease—a disease associated with employees exposed to cotton dust; 2) Improving techniques for measuring strength and length of cotton and wool fibers; 3) Improving design of

wood structures—it has been estimated that improved engineering and construction practices could save 10 to 20 percent of the dimensional lumber required in a conventional house with no loss in performance.

III. How Science and Education Can Help U.S. Agriculture Meet Changing Demands

Many variables associated with agricultural production can alter output levels. These variables include: the condition and supply of natural resources; weather; government policies; competitive position; environmental goals; and technology. The impacts of these variables are interrelated, not mutually exclusive.

Most of the increases in crop and forest yields needed by the year 2000 will come from existing or emerging technologies. Improving the Nation's competitive position will require a more efficient use of land, water, and purchased inputs such as fertilizers, herbicides, and energy. Increased production can occur without depleting our soil and water resource base if appropriate conservation practices and economic incentives can be more closely intertwined. Establishing realistic environmental goals requires a sharing of ideas between the urban consuming public and producers as well as the incorporation of environmental concerns into new technologies. Government policies are largely established in the political realm, but can be heavily influenced by careful analysis that considers economic, social, and biological consequences of alternate policies. While the weather cannot be altered at the present time, there are many realistic strategies that can be used to reduce the adverse effects of weather on agricultural production.

These variables are discussed in more detail below. For each of six broad subject categories—natural resources; production agriculture; processing, marketing, and distribution; agricultural policy; family and communities; and international activities—problems and issues are discussed where science and education can help find answers. The emphasis is on the role of science and education, but there is an awareness that new ideas are not adopted in a vacuum. Before a farmer, processor, or consumer will adopt a better approach, there must be motivating incentives like higher economic returns. Before alternative policies are considered by policymakers, they must adhere to political persuasions of elected officials.

Science programs of the future will include two common features—systems analysis and economic feasibility studies. Scientists will integrate data from basic and applied research into models that simulate agricultural activities and practices. Then, by the process of systems analysis, they will compare the effectiveness of alternate strategies before testing and validating the results in a field experiment. Economic feasibility studies should increase effectiveness of research investigations and extension programs and provide needed information for potential users of new or existing technologies. The development of microcomputers and associated telecommunication systems enhances the use of these techniques. These two features apply to most of the following categories.

A. Natural Resources

Much can be said about the importance of natural resources in the modern world. People look to land and water for the food they eat, for the fibers and other materials needed to clothe their bodies and to provide housing and manufactured goods, for building sites, for recreation opportunities, and for scenery and open space.

Average Americans often take their relationship to the natural environment for granted. Urbanization has separated the great bulk of the Nation's population from intimate contact with land and water as a producer of food, fiber, and forest products. Technological advance has removed the threat of famine and inadequate shelter, and comparative affluence has centered the concerns of most people on issues only indirectly related to their natural surroundings. Except for expressions of concern over the quality of the environment, most people now tend to view land and water resources as dependable and thus a routine input into their scheme of values. The fact that these resources are made more productive by capital investment and the addition of chemical and energy inputs does not mean that they are expendable or unimportant. In fact, their importance in absolute terms grows steadily with each passing year (Barlowe, 1972).

Soil, Water, and Weather

The 1977 Natural Resources Inventory shows that 38 percent of the U.S. cropland eroded at rates greater than that of soil formation by natural processes. Twenty percent eroded at twice this rate or greater. Sheet, rill, and wind erosion is considered excessive on 106 million acres of rangeland, 32 million acres of forest land, and 20 million acres of pastureland. Soil erosion pollutes lakes, streams, and estuaries and invokes regulatory actions by governmental units.

Some people argue that general yield-enhancing technological progress such as new plant varieties and improved agricultural chemicals will offset the effect of topsoil erosion on crop yields. Indeed, wheat yields have roughly doubled in the southeastern Washington Palouse area over the past five decades, despite continuous high levels of topsoil erosion. However, this observation does not tell the complete story. When topsoil depth is high (15 to 25 inches), loss of soil has little impact on per acre output. When topsoil depth is low (5 inches or less), the effect on per acre yield can be significant. Furthermore, the genetic yield potential of improved varieties will be restricted at the outset if poor seedbed conditions on compact clay subsoils reduce stand establishment (Walker and Young, 1983).

Soil Technology: Conservation tillage is the most significant technology being developed for producing crops and simultaneously controlling soil erosion. Reduced-tillage and no-till systems can maximize the crop residue cover on the land and conserve energy, labor, water, soil, fertilizer, and organic matter on the main food-producing areas of the earth (Wittwer, 1982). The highest priority extension activity requested by the Soil Conservation Service in 1983 was: "To accelerate extension efforts relating to conservation tillage".

However, there are still many obstacles to expanding the use of this technology. Crop residue remaining after conservation tillage acts as a mulch on the colder and wetter soils of the corn- and soybean-producing regions. This residue slows the warming and drying process in spring, sometimes delaying planting. Without plowing, some soils are vulnerable to compaction by vehicle traffic. To remove these obstacles, and others, continued research is needed on weed and pest control, tillage machinery, and alternative systems of tillage and fertilization practices.

Improved conservation practices, in addition to conservation tillage, are needed for water erosion control on steeper slopes. Historically, forage-based rotations, strip cropping, and terracing have been relied upon. Terracing, while effective in reducing erosion, has not been well accepted by farmers. In many cases, terracing is not compatible with the use of large machinery, particularly on complex topography.

An area of special concern in soil resource management is the lack of quantitative knowledge about the amount and quality of the Nation's soil resources. Without quantitative knowledge about soil degradation, including the costs of soil erosion, the extent and severity of soil compaction, or the importance of adequate drainage, policymakers are handicapped in creating effective conservation programs, action agencies cannot target their resources, and farmers continue to use conventional management practices. There are approximately 10,000 different soils in the United States, and each region and area has specific problems.

Water Management: As discussed by Boyer (1982), crop production is limited more often by water than any other production variable. Approximately 60 percent of the soils in the United States have capability limits related to deficient or excess water and nearly 60 percent of the crop loss indemnities paid to farmers are water-related. Production losses from the drought of 1980 were estimated at $20 billion. In the future, the acreage of water-stressed crops will increase because of increasing competition from other water users, declining groundwater levels in many areas, and increasing use of droughty or poorly drained soils.

Considerable progress has been made in irrigation scheduling for individual crops. Likewise, progress has been made in improving fallow efficiencies in northern areas. Other research and extension strategies for irrigated areas include increasing water-application efficiency, using irrigation return flows, and using water of impaired qual-

ity. Strategies for rain-fed agriculture include improving fallow and overwinter water-storage efficiencies, developing water-conserving tillage practices, managing snow and snowmelt, and harvesting water for run-on farming. Progress has been made in all these areas—but much more is possible. Considerable potential exists for improving the tolerance of crops to water stresses for both irrigated and dryland agriculture, but the mechanisms of tolerance need much more research. Drainage will be a continuing need for both irrigated and nonirrigated agriculture. Most subsurface drainage systems were designed and installed about 50 to 100 years ago. Many are inadequate today. In the humid and sub-humid regions, where supplemental irrigation will increase, combined irrigation-drainage systems will be needed. In regions where groundwaters are being depleted, a variety of research and extension programs will be needed to help made an orderly transition to less water-intensive technologies.

The regional diversity in the water supply and the demands placed upon it require similarly diverse educational programs to teach various audiences about the nature of such problems. Extension programs built upon appropriate research and technology should be designed to provide such knowledge so that citizens and governmental officials at the local and state levels will be able to make rational decisions regarding the problems and potential solutions.

Water Quality: As the use of land and water intensifies, water quality problems will become worse unless steps are taken now. The biological and economic effects of specific pollutants must be assessed in terms of subsequent water use so that rational standards can be established for maintaining the quality of water supplies. The Colorado River Basin is one of many examples. Salinity damages to agriculture and municipalities in that basin were estimated at $53 million in 1973, but are expected to reach $150 million annually by the year 2000 unless salt loading can be controlled.

Improved understanding of the factors affecting water quality will lead to the development of more accurate and reliable models that can be used to predict the effects of management practices on a farm, watershed, or river basin scale. In some cases, improved practices or combinations of practices will be needed. Research and extension programs on water quality should be coordinated closely with those on water management and conservation practices. The key to handling pollution concerns is to assess the major problem(s) in each area of the United States in terms of the actual or potential source of pollution and its effects, and then to develop the most appropriate responses. This will require continued close working relationships among Extension, Soil Conservation Service, Environmental Protection Agency, researchers, farmers, and others in the local areas.

Acid Precipitation: Another critical environmental issue is acid precipitation. It occurs in large regions of the United States and Canada, Europe, and Japan. Attempts to determine the economic impacts of acid precipitation within the United States are highly controversial because of the complex interrelationships and the fact that there

are potential beneficial effects as well as negative effects. Badly needed is solid evidence on how acid precipitation affects crop yields, tree growth, lake ecology, and fish and wildlife habitats.

Weather: Fluctuations in weather are the main cause of year-to-year variations in crop yields. While the weather cannot be altered at the present time, many realistic strategies can be used to reduce the effects of adverse weather on agricultural production, which in turn would reduce the fluctuations in domestic and world food supply and prices. An increasing number of crop growth and resource management models are becoming available, nearly all of which contain weather variables of various kinds such as temperature, rainfall, and solar radiation. The need now is to validate these models in a variety of field situations and make them operational in computerized information systems in many states and research centers. Other ways to reduce the adverse effects of weather include: supplemental irrigation in humid regions, breeding plants that are more tolerant of drought and temperature extremes, and adjusting the growth cycle of plants to avoid likely periods of climatic stress.

Energy

Because energy supplies and costs have stabilized in recent years, the pressure to improve energy-use efficiency and substitute domestically available energy sources for imported fossil fuels has lessened. Since one international incident could seriously disrupt world supplies, prudence suggests renewed effort in research and education. What are the most cost-effective technologies for achieving optimum energy-use efficiency in agricultural production, processing, and marketing? If necessary, energy self-sufficiency in agriculture is attainable. It will require greater use of alternative energy sources like solar, wind, and biomass. Which option is most promising and what incentives would encourage adoption? Research and educational programs need to provide more information on ways to reduce energy needs in all parts of the rural community, including homes, farms, and ranches and in processing, storage, and transportation.

Forestry

The United States is rich in forests and related renewable natural resources. These resources must be managed and used wisely if Americans are to enjoy the full complement of forest-provided values—jobs, wood, wildlife, water, range, and energy—and a varied array of recreation values. Wise management, in turn, requires scientifically sound knowledge and an understanding of human needs—material, aesthetic, and social.

Growth in world demand for forest products is anticipated to increase significantly by the year 2000 and into the next century (Section II). Therefore, the United States has many opportunities to increase exports, particularly in paper products. A wide variety of trade barriers, however, will limit the growth of exports of processed products such as lumber, panels, and paper. Efforts to ease or eliminate some of these barriers are underway.

The most effective way for the United States to satisfy the growth in domestic demand without major increases in price, and to overcome trade barriers in export markets, especially for processed products, is to increase the efficiency of growing, harvesting, processing, and marketing timber. To realize that goal, the following research programs should be emphasized:

- Develop improved silvicultural techniques to increase yields of timber, while simultaneously considering other multiple use demands. This involves the entire range of forest management practices from seed production to harvest and stand establishment.

- Genetic improvement to provide superior tree species for greater yield and increased disease and insect resistance. Forest yield enhancement is strongly dependent on genetic improvement of trees, but the long generation time has hindered progress with current breeding techniques. The new biotechnology tools offer a way to circumvent the long generation cycle of trees.

- Finding ways to reduce timber losses from destructive agents, i.e., fire, insects, and disease. Increasingly, this research is concentrating on preventive measures as well as control methods.

- Development of better utilization technologies to expand the use of currently abundant hardwood species, extend the supply of scarce softwoods, and enable the use of small or low-quality trees now underutilized or wasted.

Economic studies that provide financial guidelines to forest landowners on the economic feasibility of alternative management practices are essential. Domestic and international markets for wood products are changing rapidly and require a continuing analysis of such issues as trade barriers, comparative costs, price trends, supply status, and government policies.

Extension programs in forest land management should concentrate on improving the ability of owners and managers of private nonindustrial forest lands to derive a profitable return from their woodlots. Educational programs would deal with marketing approaches and opportunities, stand regeneration practices, timber stand improvements, and insect and disease control technology.

As the supplies of softwoods in the West become more scarce and expensive (due to declining old growth stocks, increased transportation costs, and high harvest-to-growth ratios) eastern and southern forests will either fill the gap or the United States will continue as a net importer of wood products. This shift in forest production can take place with the help of improved utilization technology. The recent development of press drying allows for the use of short-fiber hardwoods in pulp, making hardwoods more competitive with softwoods. Improved technology in reconstituted panels improves the competitive position of smaller trees, which are in plentiful supply in both the East and South. Many more technologies need to be developed.

Americans look to their forest resources for much more than commercial products. They want a pleasing forest environment in which to hike, camp, hunt, and fish. Forest managers expect the science and education community to identify the nature of conflicts between commercial uses (timber, forage, and mineral production) and noncommercial uses (recreation, aesthetics, soil stability, and water quality) and to identify opportunities that reduce competition among uses.

Range

Range is land that provides or is capable of providing forage for grazing or browsing animals. A complex array of ecosystems, characterized by a variety of vegetative life forms, makes up the Nation's rangeland base. More than two-thirds of the range is dominated by grasslands and shrublands and the balance by coniferous and deciduous forests. Ninety-five percent of the 853 million acres of rangeland are in 17 western states and Alaska. Non-federal owners control almost two-thirds of the rangelands.

Almost 61 percent of the Nation's non-federal rangelands are in poor but improving condition. Much of these lands are arid and semi-arid. They produce less than 50 percent of their forage potential. Rangelands, in addition to producing forage for livestock, provide valuable habitat for wildlife, serve as watersheds, and provide open space and natural beauty that is enjoyed by increasing numbers of recreationists.

Range research has turned from the single-purpose range livestock grazing systems approach to the ecosystem approach; that is, research is based on understanding the interrelationships of multiresource productivity and use. Responding to needs of multiple use management, increased effort has also been devoted to the study of interactions and compatibilities of forage production and livestock grazing with wildlife and fisheries habitats, watersheds, and recreation. Additional research is needed to:

- Expand our fundamental understanding of range ecology for the purpose of improving management practices to sustain productivity for both domesticated and wild animals.
- Increase production through genetic improvement of native range plants. New selections and even new species can be developed that are easier to establish, live longer, and have improved forage quality and water-use efficiency.
- Improve range resource classification, inventory, and monitoring techniques.

The present status of range management and range productivity does not adequately reflect the current state of knowledge. Much can be done to improve range conditions and increase renewable rangeland resource outputs through intensive application of existing knowledge. But effective methods and processes must be developed to transmit technology into application. The extension of knowledge involves not only the delivery but also the presentation or packaging of information for those who would use or deliver it.

Extension programs should concentrate on: the resolution of conflicts from mixed landownerships (private and public) and multiple use demands; and the rapid adoption and application by landowners and managers of new research results that will increase profits and preserve or improve the resource base.

Wildlife Habitat

Wildlife environments will continue to be under pressure from development for living space, mining and industrial development, and agricultural and timber use, as well as energy production. Large scale and continual modifications in wildlife habitats are likely to occur unless wildlife needs are considered. Without these adjustments the opportunities to maintain balanced and stable ecosystems will be reduced. Responding to the public's overall wildlife interests and values will become increasingly difficult under those conditions.

The management of resident wildlife species in the United States has largely been the responsibility of the state fish and wildlife agencies. Habitat management is the stewardship responsibility of the landowner or manager. Land use decisions on much of the privately and corporately owned land are affected by market forces little influenced by wildlife values. Public lands can be used, to some extent, to balance the modifications to habitat that are occurring on private and corporate lands. Knowledge of the habitat requirements of various species, the impacts of alternative land uses, and the means to achieve habitat enhancement effectively will be important considerations in addressing this issue.

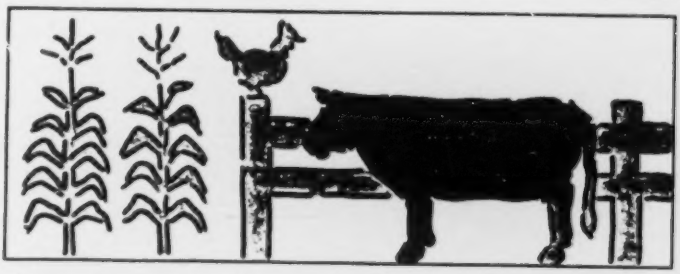
The following kinds of studies should be emphasized:

- Provide an improved base of knowledge on habitat requirements for wildlife species.

- Study the impact of changing agricultural and forest management practices on wildlife species, including threatened and endangered species.

- Find means of habitat enhancement that are ecologically acceptable and cost-effective.

Scientific knowledge and implementation techniques need to be transferred to users as rapidly as possible. Extension program efforts in this area would enable owners and managers to: improve habitat carrying capacity; increase productivity and profitability of income-producing wildlife and fisheries enterprises; increase recreational opportunities; reduce loses from wildlife pests; reduce landowner-user conflicts; enhance the environmental quality of life for both adults and youth in the community; and ensure an improved sense of stewardship to perpetuate a strong natural resources base for future generations of owners and users.



B. Production Agriculture

The production sectors of agriculture are normally categorized under crops and animals. Both are concerned with methods of production and protecting the health and vitality of the organism. Well over half the scientists in agriculture direct their investigations toward improving the performance of crops and animals.

Crops

Probably the largest problem faced by U.S. agriculture is the *high cost of production relative to farm income*. During the period from 1966 to 1979, total farm expenses increased by 320 percent, but cash receipts for farm products increased only 280 percent. Most of the increased expenses are attributable to depreciation and credit as well as equipment, fertilizers, irrigation, and fuel costs.

Agricultural research, education, and extension have brought about major increases in crop productivity. Two examples are corn and soybeans, where the yield per unit of land has increased threefold and twofold, respectively, in the last 40 years. Of this gain, half is attributable to improvements in the genetic characteristics of the plants achieved through plant breeding. For the farmer, this achievement represents a low-cost input. The rest of the gain resulted from better management practices, including enhancement of nutrient supply, improved weed control, and better timeliness of production operations. These are generally high-cost inputs. For vegetable and fruit crops, improvements in these methods have also been accompanied by advances in machine harvesting and in post-harvest storage that makes high-quality products available throughout the year.

Research on crops contributes to these increases in productivity by two primary means. First, the genetic potential for high yield can be improved. Hybrid corn is an example—switching from open-pollinated to hybrid varieties raised the genetic potential of the crop and caused yields to double.

The second approach is to improve yields in unfavorable environments. Examples are increased disease and insect resistance, more efficient nutrient acquisition, and enhanced tolerance of drought, salinity, and temperature extremes.

Potential Crop Yields: Table 4 shows how these approaches affected 12 major crops as of 1975. Record yields are one way of measuring the genetic potential for high productivity; the data show that the record yields of each crop were already very high. However, average yields realized by U.S. farmers were comparatively low. The difference between record yields and average yields was caused by factors that inhibit productivity. Diseases, insects, and weeds contributed substantially to this inhibition. However, the largest losses were due to unfavorable physicochemical environments.

Table 4.
Record Yields, Average Yields, and Yield Losses Due to Disease and Insects, Weeds, and Unfavorable Physicochemical Environments in Selected Major Crops of the United States.[1]

Crop	Record Yield	Average Yield	Average Insect & Disease Losses	Average Weed Losses	Average Losses Due to Unfavorable Environments
		Tonnes/Ha			
Rice	11.0	4.5	2.4	.9	3.2
Corn	19.0	4.6	1.7	.7	12.3
Wheat	14.5	1.9	.6	.3	11.7
Soybeans	7.4	1.6	.4	.4	5.0
Sorghum	20.1	2.8	.7	.5	16.0
Oats	10.6	1.7	.7	.5	7.6
Barley	11.4	2.1	.5	.4	8.4
Potatoes	94.1	28.2	14.5	1.3	50.0
Sugar Beets	121.0	42.6	18.6	5.3	54.4
Processing Tomatoes	152.0	66.4	22.8	22.8	62.8
Fresh Tomatoes	92.4	27.5	13.9	1.8	49.2
Sweet Corn	18.8	10.7	2.1	.8	5.2
Average Percentage of Record Yield	100	34.0	13.3	2.7	50.0

[1]Data on rice from M.D. Faulkner, Rice Exp. Sta., Crowley, LA, 1982; on processing tomatoes from W.L. Sims, University of California-Davis, 1982; on fresh tomatoes and sweet corn from D.N. Maynard, University of Florida, 1982; on other crops listed from J.S. Boyer, USDA/ARS, University of Illinois, 1982.

Crops with fruiting structures of high economic value were more adversely affected by unfavorable environments than those with marketable vegetative structures. This difference is attributable to the complexities of reproductive development, which are often highly sensitive to unfavorable environments. Even in crops with marketable vegetative structures, however, record yields were three times larger than average yields.

These data indicate that opportunities for improvements in plant productivity depend on research and education aimed at improving the performance of plants in unfavorable physicochemical environments and improving overall genetic potential. In addition, because of the substantial losses attributable to diseases, insects, and weeds, research in these areas remains important.

In the future, agricultural science and education must continue its efforts in plant breeding, biological controls for pests, methods of applying nutrients and water, techniques for harvesting and storage, and conservation aimed at minimizing soil erosion and environmental degradation. Research advancements in these areas have been the mainstay of agriculture and can be counted upon to provide a steady improvement year after year. There will be increased need for extension educators to view crop management as an integrated system, with components such as planning, cultural practices, harvesting, and marketing all included in a multi-activity package.

Future Directions: In addition to the traditional technologies, however, it appears that the fields of molecular genetics, plant growth regulation, and the metabolic basis of plant response to unfavorable physicochemical environments will be important for enhancing agricultural production in the future. These approaches have promise because of two recent changes in scientific understanding. First, there has been a revolution in our knowledge of molecular genetics that could not have been predicted as recently as 1969. The opportunity for using this knowledge to improve agricultural technologies is more fully explained in Section IV. Second, there has been an increase in understanding of how plants cope with unfavorable environments.

Basic to the application of these technologies is the need for a wide diversity of genes that can be incorporated into crop germplasm. The continuing loss of wild genotypes and land, together with increasing population pressures worldwide, places particular importance on the need for more activity in plant exploration, mutation, and advanced techniques for recombination. Central to each of these activities is the need for germplasm evaluation and conservation. Such research is long term and of high risk but of inestimable value for plant breeding and for exploring the fundamental behavior of crops.

Scientists have only recently begun to develop molecular knowledge of how plants cope with unfavorable environments. The concepts that predominated as recently as 15 years ago are changing radically. The impact of unfavorable environments is increasingly viewed as having a metabolic basis regulated by plant genes, rather than being inevitably imposed from outside the plant. Rapid changes have occurred in our understanding of how plants cope with freezing, chilling, and overheating, as well as drought. The effect of this increased knowledge is that the impact of unfavorable physicochemical environments is more accessible to genetic manipulation and is brought within reach of the techniques of molecular genetics.

Following are a few areas that hold promise:

Biological Stress—Because diseases often involve microorganisms, for which molecular genetic techniques are best understood, the promise of improvements in disease resistance is considerable.

Plant Regeneration—Tissue culture techniques for plant regeneration offer the promise of large numbers of genetically identical individuals as well as methods for understanding gene expression in plants.

Physicochemical Stresses—Many of the aspects of unfavorable physicochemical environments were previously thought to be imposed inevitably by the external environment. It is now apparent that plants have molecular means for acclimating to these conditions and that much of the plant response is under metabolic control.

Photosynthesis—Single gene products have been identified that could be modified by the techniques of molecular genetics. In particular, both ribulose bisphosphate carboxylase and herbicide-binding proteins have been observed to undergo genetic changes that alter the photosynthetic performance of plants.

Nitrogen Fixation—The molecular basis of nitrogenase synthesis and activity is increasingly understood, and genetic modification of the nitrogen-fixing capacity of both symbiotic and free-living bacteria is being carried out.

Male Sterility—Male sterility is beginning to be understood at the molecular level. This could lead to significant improvement in the efficiency of plant breeding.

Seed Proteins—Most of the proteins stored in the grain of food crops have an amino acid composition that is not optimally balanced for human and animal consumption. The possibility of inserting genetic material that would change the amino acid composition of grain protein is within reach.

Recent Changes in Crop Production: The patterns of U.S. agriculture have changed in the last few years. In 1966, the cash received for crops was 42 percent of the total receipts by farmers. By 1980, this had increased to 50 percent. This shift from animal to plant production is attributable in part to changes in food consumption. The per capita consumption of animal products did not increase between 1966 and 1980; consumption of plant products, however, increased an average of 14 percent. Some of the increase was attributable to consumption of grain and some to greater use of vegetables, melons, and fruits. Of even greater significance is the change in U.S. crop exports. In 1966, 23 percent of the total grain production was exported. By 1980 this share had risen to 36 percent.

Accompanying these production changes has been a continuing trend toward larger farms. The raising of grain crops lends itself to large-scale production methods. These units take advantage of corporate structuring of assets, computer forecasting, and advanced accounting methods. They are increasingly capitalized and make extensive use of credit. Specialty crops, while grown on smaller acreages, are also tending toward increased farm size.

In this situation, agricultural forecasting is gaining in popularity. Computers are now within reach of most operators, who are better able to anticipate pest and weather problems, income and cost relationships, and the scheduling of farm inputs.

As grain production becomes more prevalent, added research and extension will be needed to protect crops against pests that are more devastating as the cropping system becomes more dependent on monoculture and a narrower genetic base.

At the same time, research needs to emphasize ways to increase production and quality of small-acreage, high-value crops directly consumed by the population. Because of the high economic returns from these crops, advanced methods of irrigation and nutrient supply are possible, as is hormonal control of flowering and fruit sets. Many of these crops are perennial, so research requires large financial resources and years of effort. Basic knowledge of mechanisms of fruit set, propagation, and time to reproduce are often lacking. This can be a problem for farmers and commodity groups having limited resources. Consequently, there is a need for expanded, long-range genetic and cultural research to support these diverse crops.

With increasing reliance on large-scale operations, optimization and yield forecasting are becoming important features of agriculture. Since computers are within reach of individual farmers, modeling concepts can provide important means for increasing the efficiency of resource use in crop production. Science and education must provide more information and computer programs that can forecast for specific crop systems the benefit of various inputs in terms of yield, income, capital requirements, tax consequences, etc. There is a tremendous need for improving the usefulness of these tools.

Animals

Animals provide humans with food, fiber, work, fuel, fertilizer, recreation, and a vast array of cosmetic and medicinal products. Of all animal products utilized by humans, milk and meat rate first. Nonfood products include wool, hair, hides, and pelts. In the developing world, animals provide the majority of power for agricultural enterprises. Animal wastes contain millions of tons of nitrogen, phosphorus, and potassium to fertilize crops.

Even more so than for crops, animal agriculture is facing a severe cost/price squeeze. Buying patterns are shifting (e.g., increased consumption of poultry and fish) and production costs are rising faster than the market is willing to absorb them. It is important for society to address these issues, because the nutritional needs of the U.S. population are still met, to a large extent, by foods of animal origin. Science and education programs can help animal agriculture adjust to shifts in consumer buying habits and provide technologies that improve productivity.

Opportunities for Improving Productivity:[4] Today we have the same number of animal breeding units in the United States as we did in 1920, yet animal food production has increased 2.25 times. This trend can continue and even accelerate through the year 2000 to meet the increased demands projected in section II at an affordable price to the consumer. The increased production per animal can be achieved largely through improvements in three major areas: 1) forage production and utilization; 2) reproduction and genetics; and 3) physiology and nutrition.

Forage Production and Utilization: Approximately half the total U.S. land area involves grazing lands (pastures and rangelands), which produce forage as a renewable natural resource. Utilization of that forage resource provides many complementary benefits for the well-being of the American people through food and fiber production and enhancing the quality of the Nation's environment. Ruminant livestock are capable of consuming the vast forage resources that cannot be utilized directly by humans. Ruminants can provide a unique buffer for fluctuating grain supplies caused by crop surpluses or failures, and thus may be considered a strategic reserve human food supply.

Plant breeders and agronomists are improving varieties of forage plants and extending their adaptability. Extension specialists are transferring information about known technologies such as overseeding grasslands with legumes, establishing grass-legume mixtures, and improving grasses with nitrogen fertilizers.

[4]This material was taken primarily from a paper written by William Hanzel, Cornell University, for a RCA Symposium held December 5-9, 1982.

57-279 O - 87 - 30

Large losses in protein contents and digestibility occur in most forage plants as they mature. It may be possible to delay the maturity of forage plants in order to preserve their protein contents and digestibility. Significant advances in this area will likely occur before the year 2000.

Reproduction and Genetics: Current and emerging developments suggest that a new system of animal breeding could be in use by the year 2000.

Estrous cycle regulation techniques will likely be perfected so that large groups of cattle, sheep, swine, and goats will be fertile to insemination at one pre-set time. Nonsurgical embryo transfer techniques will be perfected, making possible the dissemination of embryos produced by outstanding sires and dams. Superovulation techniques will be perfected so that large numbers (100 or more) of fertilizable eggs can be harvested at one time. *In vitro* (outside the living body) fertilization and embryo freezing techniques will be perfected, so that embryos can be stored in the laboratory for indefinite periods. It will become possible to control the sex of the embryos, and fertility of the recipient animals will be greatly improved. Thus, our artificial inseminators may become "artificial embryonators", who will perform a service consisting of placing genetically superior embryos into the uteri of animals. These embryos will be conceived in the laboratory and stored frozen until needed.

Physiology and Nutrition: Increased production of meat and milk per animal, as well as improved carcass characteristics, will also be achieved through improved methods of regulating the animal's endocrine system and metabolism. Within 20 to 30 years the major pituitary and hypothalamic hormones will have been synthesized in relatively large quantities by recombinant DNA techniques, and new ways to administer them to animals will have been developed. Bovine growth hormone has already been produced in this way and shown to increase milk production in dairy cattle by about 10 percent, without increased feed intake. New and more effective drugs, especially of the "rumen additive" type, will be developed to enhance feed efficiencies. Increased use will be made of byproducts and waste product feeds.

The years between 2000 and 2030 will likely be characterized by the application of genetic engineering techniques to all classes of livestock and to the forage plants they consume. It is extremely difficult to predict the nature of the changes that may occur. Theoretically, it is possible to modify the production of hormones and enzymes in a predictable way by introducing new genetic material into the embryo. The resulting changes in production traits are not known, however, because most are affected by numerous genes.

Animal Protection Issues: Throughout the world, disease, internal parasites, and toxicants cause major losses and are important causes of low animal productivity. In the United States, they cost livestock producers, and subsequently consumers, an estimated 20 percent of the farm income from livestock and poultry products.

• New and improved methods are needed for identifying losses from diseases, parasites, and toxicants. Tests are needed for diagnosis of recognized diseases, detection of inapparent carriers, identification of new diseases or sources of loss, and assessment of losses attributable to individual diseases.

• The associations between environmental stress, nutrition, and animal health are largely unknown. Factors that influence infection by disease, including the effects of hormones on the immune system and the response of animals to vaccination, should be studied.

• Recombinant DNA technology is expected to revolutionize the production of vaccines and other biological materials that are needed to prevent disease or promote growth. Advantages of the technology are safety of the products and the ease with which abundant supplies of vaccines and materials can be produced.

In the United States, insects, ticks, and mites that affect livestock and poultry cause annual losses estimated at more than $3 billion. Insects, ticks, and mites also directly affect people by impairing th health and productivity through annoyance, debilitation, and disease transmission.

• A balanced program of basic and applied research should provide the knowledge and technologies that are needed to alleviate those losses. Methods of detecting infestations of insects, ticks, and mites need improvement, and thresholds of economic importance must be determined for species that affect man and animals.

• New and improved methods of reducing losses should be emphasized in research on the chemical control of insects, ticks, and mites that affect man and animals. Genetic methods of altering the pests should also be devised.

• Applied research will be used to combine chemical control, biological control, and other control approaches into integrated systems for the management of insect, tick, and mite populations so they can be maintained below thresholds of economic importance.

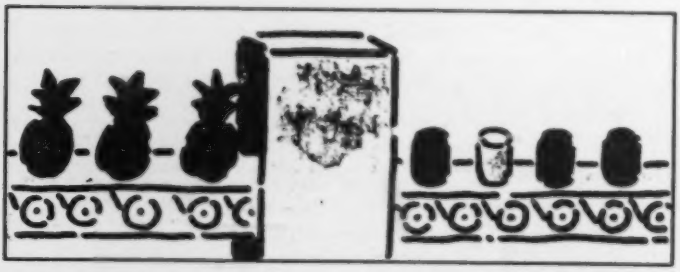
Extension programs in animal production and protection will concentrate on the use of more integrated approaches to solve problems and improve profitability of livestock operations. Multidisciplinary teams from extension, industry, and research will cooperate in problem identification and solutions. Modern communication systems will serve as a key vehicle for program delivery. Reproductive efficiency and improved stewardship and utilization of grazing lands will receive high-priority emphasis.

Food Safety, Environment, and Related Issues: In the 21st century, the consumer will expect animal food products to be even more safe and nutritious than at present. Producers and regulators need procedures for defining and certifying the wholesome-

ness of animal products (wholesomeness is generally defined as clean, free of disease, residues, chemicals, or other contaminants of any kind). This requires monitoring production systems for residues and analyzing the causes and sources of residues appearing in the final product. Additionally, science and education should develop and transfer to producers and processors cost-efficient alternatives to practices identified as causing residues.

If animal agriculture is to be publicly acceptable, producers must adopt more effective methods to prevent the pollution and environmental degradation associated with current animal production systems. To develop these methods, the current level and major sources of adverse environmental impact associated with animal agriculture need to be identified and evaluated. New, economically viable systems for utilizing animal production waste and other byproducts need to be developed. Potential uses may include single cell protein conversion of waste for feed or conversion of waste to feed, energy, animal bedding, or other useful products. Cost-effective ways need to be found to control or eliminate the presence of odors, flies, rodents, litter, and other undesirable pollutants.

An emerging issue also requiring careful attention from a public education perspective is the application of new biotechnology methods to animal agriculture and animal research. Public sensitivities are high when prospects of changing the form of living organisms are discussed, yet animal agriculture will likely adopt some of these scientific developments and producers will not want to forgo the potential improvements in productivity.



C. Processing, Marketing, and Distribution

The importance of processing, marketing, and distribution is evidenced by the fact that two-thirds of the retail cost of food is associated with this segment. It is expected that roughly three-fourths of the retail value of food, fiber, and forestry products will be represented by these activities by the beginning of the 21st century. The beyond-the-farm-gate sector of the U.S. economy will become increasingly critical to national employment, the inflation rate, and the balance of payments.

As we look to the year 2000 and beyond there are three major areas of concern: 1) increasing transportation costs; 2) processing and packaging efficiencies; and 3) storage and handling issues.

Increasing Transportation Costs

The problem of increasing transportation costs is caused by several factors, including the increasing cost of energy, regional adjustments in agricultural production, and the shifting centers of population. Intermodal transportation systems are needed which utilize the most efficient aspects of motor vehicles, trains, airplanes, and ocean vessels. While the motor truck has been a dominant factor in agricultural transportation in the second half of the 20th century, the energy efficiency of rail services for intermediate and long hauls will make rail transportation increasingly important in the 21st century.

The higher cost of transportation may force the relocation of agricultural production for high-value perishable agricultural commodities closer to population centers. As a result, innovative production systems may need to be explored and evaluated. A few examples of these systems include hydroponics, solar energy greenhouses, and waste heat utilization.

A transportation system must be developed to move raw agricultural commodities and finished products to consumers more efficiently. This requires an integrated research and development program with participation of government, private, and university sectors. An initial requirement is the need to open up communication among these three groups to ascertain the barriers to productivity growth and efficient resource use. A specific example is standardization and unitization of containers used in the food industry. Can uniform standards be developed to permit palletization and unit handling of all types of food products, serving all types of transport carriers? What is the economic impact of current and alternative government regulations affecting the transportation system?

Processing and Packaging Efficiencies

Costs associated with converting raw agricultural commodities into finished products are expected to increase. These increased costs will influence processing and packaging efficiencies. Problems with productivity growth efficiency are expected, particularly from energy inputs, labor, raw materials for packaging, and capital. The need for a low-cost, year-round, varied food supply will require continued improvement in this segment of the food and agricultural system. New methods of food preservation which use fewer purchased energy inputs are needed, as are technologies which lower labor costs, possibly via robots.

For most industries that process and distribute farm products, the rate of labor productivity growth (output per employee hour) has declined since 1972. While labor productivity improvement is an obvious place to start, virtually no research is looking at improving total factor marketing productivity of either firms or marketing systems.

Low productivity in this sector costs the United States jobs, as labor-intensive production and processing are shifted to other nations. Research on improving productivity should emphasize: 1) improving distribution of food and fiber; 2) maintaining and measuring product quality, with concurrent reduction in losses and longer storage life; and 3) developing new opportunities for agricultural products. Productivity can be gained in the restructuring of container sizes (i.e., modular containers) to make more efficient, unitized loads. This would improve handling and storage efficiency, but much research is still needed to document the costs, benefits, and potential beneficiaries.

New technologies in processing and packaging will be necessary to make possible the continued availability of a low-cost, year-round food supply. This research must be coordinated with agricultural production research and development. Traditional plant and animal breeding programs, plus new efforts in genetic engineering, must be coordinated with processors and retailers.

The environmental issues related to processing and packaging will continue into the 21st century as shifts occur in the food and agricultural system. The increasing expenses associated with the disposal of agricultural byproducts and wastes from processing operations will make their utilization more attractive. This will allow more efficient use of agricultural commodities, while at the same time minimizing the adverse effects on the environment.

Storage and Handling

Most agricultural commodities experience numerous handlings and pass through short- or long-term storage facilities as they move from the farm to the consumer. These handlings and facilities contribute to excessive food costs and losses. Although post-harvest losses of agricultural commodities have not been adequately evaluated, it has been estimated that research on reducing food losses due to pests alone could save $1.5 billion annually in the United States. Research on reducing the storage and transportation losses of fruits and vegetables could increase the supply of these products from 15 to 30 percent.

Most losses occur because control procedures are considered too costly. Unfortunately, deeply entrenched operating procedures tend to accept certain post-harvest losses as normal consequences of dealing with a commodity. Relatively small losses of cereal grains here and there throughout post-harvest handling and processing attract little attention, even though the total loss may be highly significant. Effective and economical technologies must be developed for improving storage and handling.

Storage technology must be upgraded to meet the challenge of storing new varieties of commodities and controlling insects and bacteria that have become increasingly resistant to current control methods. Research is needed to determine storage, drying, and processing conditions (temperature, humidity, etc.) that will minimize the growth of bacteria and molds. For commodities such as horticultural crops, this reduces incidence of rot and, therefore, the occurrence of mold toxins and loss of nutrients.

Research can find ways to ensure good arrival condition for products that are not presently exported. The quality of cereal and oilseed products can be increased and losses can be minimized if transportation, storage, and handling procedures are improved. Research is needed on product mechanisms that change under storage and handling conditions; for example, the effects of chemical residues on the nutrients and keeping quality of peanuts and peanut products for the export market.

Reduction of losses presumes the ability to identify the causes and magnitude of the loss, assess the likelihood of preventing it, and assign cost/benefits to alternatives in order to decide whether to adopt them. Unfortunately, this is not the case. The movement of new varieties and improved qualities of agricultural products through conventional and, in some cases, outmoded storage facilities with poor handling methods creates the risk of increased losses and an inability to maintain a competitive position with other nations.

Extension programs beyond the farm gate are directed primarily at processor and distributor audiences. Many of these firms lack the resources to be aware of recent innovative techniques and management practices that can improve operating efficiencies and enhance product quality.

D. Agricultural Policy—Including Adjustment Concerns

Public policy involves the creation and management of institutional arrangements that affect the behavior of farmers; those involved in supplying inputs and marketing food products; and consumers. Appropriate policy choices can remedy market shortcomings that would otherwise harm the economic well-being of consumers, farmers, and rural society.

Intelligent policymaking requires a knowledge base for the agricultural economy that is not only descriptive and historically accurate, but also useful for predicting the consequences of policy alternatives. While social scientists have made substantial progress in understanding the functioning of commodity and input markets, we are far from the level of understanding necessary to meet present and future challenges in policymaking. We need to develop a better understanding of how farmers, consumers, and others respond to market and policy institutions; to anticipate the individual and aggregate implications of various policy actions; to identify and provide for the information needs of those involved in the U.S. agricultural economy; and to prepare those who will operate within the agricultural system to do so with full knowledge of market and policy institutions.

Policy issues expected to be important in the U.S. agricultural economy in the year 2000 and beyond have been identified in the following areas: (1) the position of U.S. agriculture in the world economy; (2) effects of recent developments on size, cost, and asset distribution of farms; and (3) the role of the federal government in the agricultural economy.

Position of U.S. Agriculture in the World Economy

As shown in Section II, world commodity markets are crucial in determining the economic health of U.S. agriculture. In recent testimony before the U.S. Congress, Secretary of Agriculture John Block identified six causes of recent farm economic problems. All six—high worldwide production, past U.S. export embargoes, global recession, the strong dollar, agricultural protection policies in foreign countries, and financial difficulties of our foreign customers—involve the world economy. Yet, the economic role of only one of them, high production, is well enough understood to have clear policy implications.

For the others, we either do not have a full explanation of their importance, or, if we have a well-developed theory (as in the role of the strong dollar) we do not have sufficient practical knowledge.

Research is needed on the economic and other factors that motivate farmers, consumers, and governments in the United States and elsewhere around the world. A much better understanding of who the world agricultural economy operates and how individual farmers and consumers behave within it is required. Just how differently do farmers, consumers, and taxpayers behave in the United States, the European Community, Brazil, Argentina, Australia, Canada, and other countries? Why is the United States a "residual supplier and adjustor"? If the U.S. were to attempt to change its role in world markets, how would major competitors and customers react?

In many instances, scientific investigation will involve a fundamental investment in improved information based on events abroad that influence world trade. How are prices determined? To what economic signals (e.g., market price and government price support) do U.S. and foreign farmers respond in making production and marketing decisions? Just how responsive are they? If foreign producers respond to U.S. farm program supports, how does this interaction occur? What does it imply for U.S. policymaking?

Over the past decade, U.S. agriculture has moved from a closed to an open economy. Exports now play a crucial role in the economic health of the U.S. farm sector. Research into the nature of world markets, as already noted, is basic to the performance of U.S. agriculture in the years ahead and to the setting of U.S. agricultural and trade policy.

Extension programming must be broadened to not only make farmers and others more aware of international markets but also to increase their knowledge of the workings of these markets; i.e., the economics, politics, and other dimensions.

Adjustment Needs Relating to Size, Cost, and Asset Distribution of Farms

Agriculture in the United States is evolving from a way of life into a large-scale business. In 1981, agricultural production units were made up of 112,000 large farms, which produced 49 percent of the U.S. farm output; 582,000 medium-size farms, which produced 38 percent of the output; and 1,742,000 small farms, which produced 13 percent of the output (Council for Agricultural Science and Technology, 1983). What are the long-term implications of this trend, e.g., ownership patterns, economic vitality of agricultural and rural communities, as well as the cost of food to consumers? At issue too is the role of technology in this development, e.g., what technology best serves the adjustment needs of small, medium, and large size farms?

The link between farming and the subsequent stages of the food system is complex and growing more so. There are fewer buyers and larger buying firms. This increased concentration has led to many changes, including the greater use of contractual arrangements and pre-arranged pricing procedures, suggesting that some producers will experience greater difficulty in obtaining inputs and entering some markets.

These and other changes over the last two decades are expected to continue. The food system will continue its shift from a commodity-production orientation to a consumer-product-merchandising orientation. The agricultural production sector, once the direct supplier of many consumer food products, is now the source of raw materials for a food system dominated by processing, distribution, and marketing. And the agricultural sector increasingly will focus on international markets. All of these trends suggest that agriculture will become more dependent on national policies and world development—activities that introduce price instability for commodities as well as inputs. The agricultural sector has demonstrated the capacity to respond, but certain classes of farmers and portions of the agribusiness sector find adjustments to these conditions difficult. The small- to medium-size full-time farm is especially vulnerable. These farmers often are heavily indebted and experience cash flow problems.

As the participants in the agricultural sector adjust to change, public intervention is needed at times to facilitate these adjustments to help maintain a stable and viable agricultural industry. This assistance is achieved through direct governmental policies and programs such as price support and credit programs, but also through production and marketing research designed to help those in economic difficulty.

Extension plays an important role in educating producers, consumers, and others about the farm sector—its cost and return structure, and implications for financial viability under various economic and policy settings.

Role of the Federal Government in the Agricultural Economy

Periodic excess supplies of agricultural products have created economic and political crises over the past 50 years, and will almost surely continue to do so in the future. As the United States assumes a more active involvement in world markets, the uncertainty that weather and international economic events bring to the demand for food products will give rise to an uncertain operating environment for farmers, marketers, input suppliers, and consumers. Policies will, no doubt, be advanced in response to the periodic occurrences of surplus and high demand. Research is needed to develop longer-term anticipatory policies that meet society's interests in stability for the agricultural economy. This will require the extension and adaptation of economic theory, the development of necessary data bases, and further evolution in our formal analytical capabilities.

Farm organizations, public interest groups, the executive branch, and the Congress need objective economic input into decisions. For the democratic process to work, policy alternatives and their consequences need to be frankly and openly discussed. An improved forum of interaction between policy analysts, policymakers, and the public is needed. The processes—and incorporated values—by which the results of policy analysis are input into policy decisions need attention with a view toward openness, clarity, and general understanding.

E. Families and Communities

Families in rural and urban communities have a major impact on agriculture through their consumption and nonmarket production practices, their provision of human capital, and their concern about the quality of the environment. The agriculture sector, in turn, influences family and community well-being. Food is a large item in the budgets of consumers, the largest item for some, and is purchased more often than any other. Consumers continue to express concerns about nutritional values, additives, chemical residues, honesty of grades and standards, and price. Economic well-being of farm families has an indirect influence on communities, especially those whose resource base is heavily dependent on agriculture. Economic well-being of all families is a significant factor affecting the overall economic status of the country. The

legitimacy of the issues raised by environmentalists will continue to be debated, but the consciousness that this movement has raised among non-farm residents is not likely to disappear.

Human Nutrition

The well-being of an individual or a nation depends upon people having nutritionally adequate food. Problems arise when there is an imbalance between the food consumed and nutritional needs. There is increasing awareness of the relationship between health and food. The role of nutrition in maintaining health—or the role of faulty nutrition in causing or contributing to disease—is of greater concern as people live longer and seek to remain free of diseases associated with aging. In addition, there is a growing interest in possible relationships between food and mental well-being.

Nutrient Composition and Human Nutrition Needs: Change in the nutrient composition of the food supply is accelerating. There are changes in plant varieties, animal carcasses and processing—all potentially altering the nutritional value of food. We need to improve our capability for measuring nutrients in food. These methods must be reliable and suitable to a variety of applications. Knowing the amount of nutrients in food is not the whole story. We must also measure the extent to which nutrients present in food can actually be absorbed. Current animal and human experimental methods need improvement.

To improve the output of workers it is important to understand the relationship of what people eat to their mental and physical performance. Additional research is needed to identify changes in mental and physical functions at different ages and under conditions of marginal malnutrition. Biochemical and clinical indices need to be developed that correlate well with performance measures. Fundamental studies are needed to identify the mechanisms the body uses to control energy intake.

Current ability to obtain accurate information about what people eat is greatly limited. Such information is required for reasonable planning and for education purposes. Information can be obtained about the total amount of food "disappearing" in the Nation, but there is little or no information about how much is eaten by people, how much by domestic animals, and more importantly, how much is lost in various steps of processing and distribution and in household waste.

More emphasis needs to be placed on providing the general population with credible information about nutritional requirements. This information should emphasize the wise use of foods for enjoyment and for maintenance of life-long health.

Extension programs in foods and nutrition need to concentrate on the safety, wholesomeness, and health implications in the shipment, handling, storage, preparation, preservation, economics, and utilization (waste elimination) of food by the retailer,

consumer, and home producer. These programs should provide the individuals and families the knowledge base with which to make informed decisions for optimum safety, nutrition, and health. The information sources need to be based on research, then tailored for optimum understanding and usefulness according to the age, ethnic, education, and economic characteristics of the audience.

Role of Nutrition in Aging and Health Maintenance: Fundamental improvement in the health of an aging population requires a better understanding of how food affects both the maintenance of physical and mental performance during aging and susceptibility to diseases such as heart disease, hypertension, and cancer. Fundamental research on the role of nutrition in altering the rate at which people age, including the rate at which lean body tissues are lost, should be increased. This will involve studies with cell cultures and animal models in addition to long-time studies in human populations.

The most appropriate vehicles for educating the public on the usefulness of aging research should be investigated and then developed. People need to know how to meet nutritional needs with limited financial resources and limited mobility and how nutrition can affect the diseases commonly associated with aging. As new information is uncovered, it should be transmitted in a clear, concise form to all relevant parties.

Youth, Family, and Community Development

Science and education must deal with the challenges that youth, families, and communities will face in meeting the demands for the future production of food, fiber, and forest products. Efficient production no longer depends only on scientific discovery or technological application. The era of simplistic, unencumbered decision-making—public or private, individual or group—is past. The productive capacities of people, the economic and social structure of communities, and the effects on the environment of production and consumption activities all must be taken into account.

Rural Economic and Human Resource Base: Rural areas survive according to the strength and viability of their economic base and they reflect this in their essential character. From 1940 to the late 1960's, rural population declined significantly because of farm mechanization and consolidation. Beginning in the 1970's a reversal occurred and by 1980 approximately 3.5 to 4 million more people had moved into nonmetropolitan areas than had moved out. In the 1970's non-farm sources of rural employment increased at above-average rates, e.g., in mining, service businesses, wholesale trade, communications, public utilities, finance, insurance, and real estate. In addition, there has been significant growth in transfer payments such as retirement, social security, and government support programs.

This alteration in the rural economic base over a 40-year period has had significant impact on production agriculture and on resource use. In addition to the increase in off-farm employment of farmers and their families, many rural residents do not now have a direct interest in farming. They are concerned more about the appearance of the rural landscape; building homes, businesses, and roads; and recreation opportunities.

Studies need to be conducted on how farmers and other rural residents can most efficiently share land, labor, and capital resources. Local governmental units, such as county councils and development boards, make decisions on land use zoning, taxation, water developments, and waste disposal that affect all rural residents, including farmers. These local units of government and other interested parties need much better information for making decisions than they now have. Improved knowledge can help decisionmakers reduce conflicts and create a better environment for farmers and their non-farm neighbors.

People in rural and urban areas need more job training, better information systems, and more flexible ways to upgrade skills. More importantly, people—especially youth—need reinforcement and human support systems that will encourage less antisocial behavior and more productive pursuits. The need for upgrading human resources will challenge all our institutions to: 1) provide improved information on market trends and opportunities for both youth and adults; 2) provide training opportunities that will help keep skills current and productive; and 3) encourage public and private-sector investments necessary to keep human resources productive. Rural areas present particular challenges in serving the poor, elderly, and youth due to limited transportation options and the effects of low population density. To encourage these developments, researchers and extension specialists need to work with communities and to identify consequences of leaving human development to chance.

Environmental Issues: Criteria for selecting agricultural production and processing practices and assessing new technological developments are being broadened. We have come to realize that what promises to be best for the producer in the short run may not necessarily be best in the longer run for either the producer or society. In addition to finding more efficient use of production inputs we recognize that there is a need to incorporate environmental protection goals into our technologies. How can fertilizers, herbicides, and pesticides be limited to their intended use and not cause off-site damage? How can animal production units be better integrated with other uses of the rural environment?

On the other side of the coin, the rural and urban population centers need to find better ways to dispose of their waste materials. Much of these wastes are improperly dumped in rural areas now, causing controversy and conflict. Improved waste management can occur using known reclamation techniques and through the active pursuit of new practices such as converting wastes into useful economic products. In-

creased understanding of local environmental issues by producers and consumers can help to obtain a more desirable balance between technological development and preservation of the natural environment.

Family and Consumer Programs

The economic well-being of both rural and urban families depends on their level of purchasing power, income stability and resource management skills. Programs in the consumer area cover the interactions people have with the marketplace as income earners and as purchasers of goods and services, and the production, consumption, and management activities at home that affect how well families use their resources. Improvements in the well-being of consumers that result from these programs are returned as enhanced human resources that will increase productivity of farms and other sectors of the economy.

Current national trends will influence the direction of programs focused on the consumer and families.

- The first is the complex and uncertain environment in which families must make economic decisions and manage income. For farm families, net farm income and farm debt levels have been a concern for the last several years; for all families, the relative stability of prices and sustained growth in real incomes of the 1950's and 1960's gave way to inflation and unemployment in the 1970's and early 1980's. When economic conditions are relatively stable, plans are often based on the assumption that the future will be much like the present. That assumption is no longer valid.

- Second, to expand their level of real income and provide greater income stability, many families have become two-earner families. In 1981, 51 percent of all wives were in the labor force, compared with 41 percent in 1970. While some wives work for personal satisfaction, the majority enter the labor force out of economic necessity. Among farm families, for example, over half of the farm women who work off the farm report that they do so to provide money for their households and farms.

- Third, the living arrangements of the population have changed to include more single-parent families, particularly women, who are likely to have incomes considerably below the median and who are likely to have less time to manage their resources. In addition, the population includes more elderly persons living alone.

- Finally, the lengthening of the life-span and the resultant increase of older Americans in the population will continue. This demographic change is the result of increased life expectancy and declining birth rates. By 2050, it is estimated that the population of persons age 65 and over will make up more than 20 percent of the population, compared with 11 percent today.

Data Base Needs: Improved coordination of existing national, regional, and local data bases would make them more useful in research and education programs. Researchers and educators need to find ways to predict the consequences of management practices and decisions. To determine what leads to family economic stability and progress, reliable measures of economic well-being need to be developed and tested. Comprehensive data are needed on current resource management practices, marketplace activities, and financial resources of elderly individuals and households. In addition, retrospective data are needed on major financial decisions, major changes in family status, financial resources, and ability to function at home or in the marketplace.

Education Resource Needs: Although the late 1980's may offer a break from economic uncertainty, families will face a much more complex environment. Financial and other consumer services will be deregulated. Technological advances will change both the way consumers receive information and the way they are billed for services. These factors will expand consumer choices and increase their decision-making responsibilities. Changes in federal and state laws presage growing reliance on individual responsibility and decreased institutional involvement in family financial affairs.

The general aging of the U.S. population suggests that in the future, with proportionally fewer workers and more retirees, a smaller portion of retirement income will be provided through government and social programs, such as Social Security. Retirement planning may need to refocus on independent sources of income such as savings, investment earnings, and part-time or intermittent employment. The desire of older persons to maintain their own homes and the increasing geographic separation of families may make it difficult for the very old and others with physical limitations to obtain needed goods from the marketplace, maintain a safe and comfortable physical environment, or otherwise provide for their own basic needs.

As families seek to improve their security through expertise in management and decisionmaking, electronic technology will provide needed outreach potential. Extension efforts must focus on using all media in new ways, using computers to process the increased amount of information needed to make decisions, and helping consumers select and use appropriate computer hardware and software for farm and home needs.

F. International Activities

The United States has a long and enviable record of sharing its resources and knowledge with other countries in the continuing effort to promote economic stability, reduce poverty, and solve world food problems. President Reagan, in a letter to Congress on July 11, 1983, noted recent important developments in international science relationships and stated that they reflect "...one of our principal foreign policy goals—to give science and technology a more prominent position in our relations with other countries." The President noted that "...international collaboration can

help advance many of our own national interests," and expressed his commitment "...to using the advances in science to overcome both national and international challenges."

While international programs in the agricultural sciences make up an extremely complex system, U.S. agriculture has the basic ingredients to insure that its role is one of leadership. They include: 1) a strong and viable U.S. agricultural science system, 2) a solid and proven university-USDA relationship, 3) an effective partnership with the private sector, 4) policies which articulate and give emphasis to scientific cooperation, and 5) experience in a wide range of international cooperative activities. Future plans and policies can build on the present agricultural science system.

Advantages of Technical Exchanges

Scientific and technical exchanges with other countries make it possible to obtain and share agricultural data, collect exotic germplasm and biological materials, and share information that can improve the efficiency of forestry, crop, and livestock production.

Some developed countries are more advanced than the United States in knowledge and state-of-the-art technology in selected scientific areas. Western European countries and Japan are on the leading edge of knowledge in biotechnology. Japan, for example, is the world leader in continuous fermentation technology. Other countries are more advanced in areas such as dry-land productivity, water-use efficiency, use of controlled atmosphere environments, tissue culture, irradiation sterilization of foods, and control of certain animal diseases.

A concerted effort is needed to promote scientific cooperation with these countries. The number of agricultural scientists in Japan, Western Europe, and the U.S.S.R. has increased more rapidly than in the United States over the past 25 years. Much of Japan's economic success has been driven by government investment in development and emphasis given to the educational system. Our collaborative efforts are limited and need strengthening.

Training

USDA and land-grant universities cooperate to train agriculturists from developing countries and to strengthen the capabilities of USDA and U.S. colleges and universities in areas of importance to international research and development. These programs have made it possible to train thousands of foreign students in the United States and many short course participants in foreign countries. The expertise required by USDA agencies and U.S. universities over time covers nearly the entire spectrum of disciplines. Thus, the short supply of expertise in the U.S. agricultural sciences also affects the international program efforts of U.S. agencies and universities. Additionally, U.S. scientists and educators need more experience and training in international programs and policies such as small farming systems, small-scale marketing systems, new crops, agricultural research administration, and integrated research and extension applications under field conditions.

IV. Needs of Science and Education System to Continue Solving Problems of U.S. Agriculture

The material in Section III shows how science and education programs can help U.S. agriculture meet changing demands. To continue that assignment, the science and education system must train future scientists and managers, maintain and improve its knowledge base, and integrate new equipment and tools into its daily operations. In other words, the science and education system needs to continually revitalize itself. It is important to remember that tomorrow's gain in scientific agriculture has its foundation in the healthiness and vitality of today's science and education community.

The following topics are addressed—scientific expertise needs, biotechnology developments, information systems and computers, maintaining a scientific base, and equipment and facilities.

A. Developing Scientific Expertise in Agriculture

This Nation's agricultural system is increasingly dependent on high technology. To maintain and improve productivity levels, manage the resource base, provide high-quality products, and protect the environment requires a constant supply of food and agricultural scientific expertise. Currently, there are severe shortages of trained faculty to teach and conduct research in such areas as biotechnology, food sciences, human nutrition, animal health and reproduction, soil and water sciences, international marketing, and agricultural engineering.

Faculty Development and Inducement Needs

Many agricultural scientists and faculty received their formal education 20 to 30 years ago. These scientists most likely require additional training in order to operate in today's scientific environment. Other factors contributing to the decline of agricultural scientific expertise at universities are inadequate faculty salaries and limited promotion opportunities. These factors make it very difficult for universities to retain highly qualified agricultural scientists. Some faculty members have left for positions in industry, where salaries and state-of-the-art research facilities are more attractive. Others have gone to better financed schools of science. This drain of agricultural scientific talent from universities and the public sector to agricultural industries threatens the resolution of high-priority problems of agriculture. The private sector is not likely to address problems or conduct activities primarily in the interest of the

public good: basic and disciplinary research, training managers and scientists, or addressing environmental and natural resource issues.

Unless something is done, it is probable that the brain drain from agricultural colleges during the next 10 years will be similar to that from engineering colleges during the past 5 to 10 years. Faculty development (including retraining) and inducement strategies must be augmented. Fringe benefits and incentives for qualified scientists to remain in faculty positions must be created and well articulated. These might include: a) more consulting for pay; b) salary supplements; c) named professorships; d) changed patent policies; e) contractual agreements; f) partnership agreements; g) improved space and equipment; and h) part-time appointments (Division of Agriculture Committee on Biotechnology, NASULGC, 1982).

Graduate and Undergraduate Programs

Graduate student programs in the high-tech fields are not attracting sufficient numbers of students to meet the need. At universities, research is inextricably linked with graduate education programs. The primary source of support is research formula funds, grants, and contracts.

Another facet of this issue is the decreasing enrollments of undergraduate students in agricultural sciences. Agriculture, like other scientific and technical disciplines, must compete for the limited number of students who acquire sound scientific preparation in the secondary schools. Colleges of agriculture must dramatically modify curricula emphases and instructional programming and management in a number of scientific disciplines. For example, a recent survey showed only two land-grant universities among the 10 top-ranked schools offering graduate programs in cellular and molecular biology (University of Wisconsin—fifth; University of California at Davis—eighth). Student development efforts must increasingly focus upon the professional nature of food and agricultural careers. Traditional images need to be modified so that prospective students will more objectively evaluate career opportunities in agriculture along with other professional disciplines like medicine, law, and engineering. In addition, current degree programs must change to accommodate the expansion of interdisciplinary courses and curricula that encourage the use of electronic communications to enhance interstate and interregional research and teaching.

B. Biotechnology in Agriculture—New Tools for the Oldest Science

With the discovery of the chemical structure of the genetic code of life some 30 years ago and the subsequent development in the past 10 years of gene-splicing techniques:

- Living organisms can be harnessed for the production of large quantities of specific biological products.

- Sexual reproduction can be bypassed in the transfer of specific desired traits between plants, animals, and microorganisms.

• DNA, that master molecule of heredity, can now be studied close up in ways not imagined only a few years ago.

These new abilities, along with other advances in such areas as microculture, cell fusion, regeneration of plants from single cells, and embryo recovery and transfer, are creating vast new opportunities all across the agricultural sciences. The tools of biotechnology are being applied to viruses and bacteria, to insects and weeds, to plants and animals, in all stages of their life cycles from replication through aging.

Improving Our Ability to Manipulate Genetic Material

Agricultural scientists increasingly speak a common language, centering on the cell—the basic unit of life. The critical importance of single cells lies in the fact that they are the units into which engineered genes are likely to be introduced—by transfer, by cell fusion, by microinjection. Microculture of organs, tissues, and cells also offers the potential for rapid screening of large populations in the earliest stages of growth.

Major efforts are being placed on finding ways to culture single cells from a wide number of agronomic plants and to regenerate them into whole organisms with the genetic message intact and expressed properly. In animals, embryonic single cells—fertilized eggs—may well be the recipients for gene transplants. Techniques such as embryo recovery, splitting, and transfer, whose development had little or nothing to do with the new biotechnology techniques, are playing critical roles in genetic engineering efforts.

Other new and powerful techniques now make it possible to determine much more quickly the precise chemical makeup of genes and their protein products, condensing into days what might have once required years to accomplish. Genes can also be located in their chromosomal packages relative to one another much more easily than in the past. More difficult, however, is the identification of the mechanisms regulating gene expression—what turns any given gene's activity on or off. We know very little about these controls which ensure that genes for a specific activity are operating when and where they are supposed to for proper growth and maintenance of the organism. A great deal of basic knowledge must be assembled regarding these controls and other interactions going on within and among cells before the improvement of plants and animals through gene transfer can be intelligently accomplished.

Understanding Defense and Messenger Mechanisms

A number of research areas in agriculture are being looked at today to see if and how new biotechnologies can be used to solve problems not approachable before. For example, new techniques now allow much more detailed studies of the defense systems in plants and animals than was ever possible in the past. New knowledge of the immune system in animals promises improved approaches for disease and parasite control and faster, more accurate diagnosis. More effective ways for increasing the plant or animal's own genetic resistance to pests and other stresses are envisioned. Con-

versely, improved techniques for sabotaging the defense systems of insects, weeds, and other pests also seem possible.

A growing understanding of how the chemical messengers we know as hormones operate as intermediaries in growth and development processes also promises more progress in an area that has been studied extensively and has seen much progress in the past.

Use of Model and Simulation Systems

Model systems and computer simulations are being developed specifically for agricultural research, and more are needed. The fruit fly, for example, has served as an invaluable model for the study of genetics, but models based on the physiology of agronomically important insect pests, such as the tobacco hornworm, are also needed. Petunia and wild tobacco make excellent laboratory plants, but corn, rice, soybean, potatoes, and wheat are also examples of model systems important to agriculture. Information will have to be assembled on each of our agronomically important crops in any event before gene transfers involving them are practical.

Applied and basic research in agriculture are so intimately intertwined in the biotechnologies that many practical spinoffs may be put on line while fundamental inquiries continue to pursue the basic knowledge necessary to make wide-ranging applications possible. Payoffs are aimed at increasing the efficiency with which we produce our food and fiber; increasing the quality of our farm products for markets at home and abroad; and increasing our storehouse of fundamental knowledge on which the next round of major advances in agriculture will be built.

C. Information Systems and Communication Technology

When the United States shifted from an agriculturally based economy to one based primarily on goods and services derived from an industrial economy, agriculture adjusted its farming practices to take advantage of these changes. U.S. agriculture is once again faced with major changes occurring in the economy, as we shift from a primarily industrially derived economy to one based on the production, processing, distribution, and utilization of information. Continued advances in communication and information technologies will revolutionize the ability to manipulate and communicate information.

Scientific and Extension Applications

The new tools provided by information and communications systems will provide individuals with ready access to current data for improving the management and productivity of their operations. Electronic mail will enable scientists to make daily contact worldwide with colleagues working in the same research area to discuss the most fruitful approaches to problems. When necessary, a scientist will be able to bring worldwide expertise to bear very quickly on problems which would benefit from a cross-disciplinary approach. And of course, each researcher will be notified daily of new projects and online publications in his or her area of interest. At some point, the

researcher might even have access to a colleague's laboratory notebooks as they are electronically updated.

We have sufficient experience with modeling to know that it is effective. The Agricultural Research Service has developed several models—including the Universal Soil Loss Equation (USLE); Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS); and Simulation of Cotton (SIMCOT)—that simulate major components of agricultural systems. Other organizations have developed extremely useful economic and management models for agricultural systems. Through state-based networks, such as Computerized Management Network (CMN), Agriculture Computer Network (AGNET), TELPLAN, and Fast Agriculture Communications Terminal Systems (FACTS), Extension has made diverse models available to farmers, agricultural producers, homemakers, community leaders, and youth.

Applications on the Farm

At the beginning of a new day, farm and ranch operators will be advised by their home terminal which actions are necessary to maximize daily operations. The terminal may even sound an alarm during the night if conditions sensed by the system move outside the bounds of acceptable limits. Livestock health will be automatically logged each day based on signals transmitted by embedded sensors monitoring heart rates, metabolism, and growth. Grain elevators will be driven by computer-operated robots. Weather data from the county satellite dish will be anlayzed at home using microcomputer programs. Available farm workers will be located by searching the migrant harvesting database; cost per hour will be negotiated by electronic mail. Operators will search the computerized database for research results on new crop varieties that would be well-suited for the particular soil and climate conditions found on their farms. Readouts from the automated irrigation sensors will keep the operators advised of moisture requirements. These are only a few examples of the many possible applications. An application of computerized farming was described in a recent article (Sept. 21, 1983) in the Wall Street Journal entitled: "Cows on Midwest Farm Get Automatic Reward for Giving More Milk."

Support Activities

The initial impact of these trends will be to confront end-users of agricultural information with a bewildering variety of databases, systems, and technologies. The need for information specialists to assist end-users will be extensive. It is also time to institute quality control factors to guarantee the most appropriate formatting, programming, and quality data at the input end. Information specialists can assist users when the information is accessed, but controls are needed on the amount and quality of data that enter the system.

Another need is to train people in the use of these tools. Training is needed to encourage computer literacy among professionals and among adult and youth clientele. Agricultural agencies also need to encourage expanded use of satellite networks to provide greater educational opportunities to local clientele.

The U.S. agricultural system has long known that ready access to the right information at the right time is the key to success in managing inputs, production, marketing, distribution, and consumption of food and fiber. The adopting of improved agricultural techniques continues to be limited by constraints such as access to capital, awareness of appropriate technology, and awareness of feasible alternatives. Emerging information technologies hold the key to getting the right information to the right people at the right time and thus helping producers overcome current constraints in the American food and fiber system.

D. Scientific Requirements for Maintaining Technology

Modern agriculture is a highly technical industry comprising hundreds of thousands of relatively small individual firms, producing hundreds of food, feed, and fiber commodities locally adapted. Production agriculture is site-specific, and technologies must be adapted to individual soil and climatic conditions. The usefulness of many agricultural technologies is in proportion to the proximity to the site for which they were developed.

Maintaining and Updating Agricultural Technologies

Technologies, like all man-made tools, age and become obsolete. This is true of physical technologies like dams and roads; it is true of mechanical technologies like trains, tractors, and combines; and it is true for biological technologies such as medical practices, plant varieties, livestock breeds, and pesticide uses. Biological systems are intrinsically dynamic.

- The average useful lifetime of a new plant variety is about 10 years. Change in wheat yields from 1875 to 1975 provides one example. The cumulative gain in productivity for the first 20 years was only 3.1 bushels per acre. Since then the gains in productivity have been substantial and future projections suggest continued increase. The first improved wheat variety was released by the New York Agricultural Experiment Station in 1920. Wheat yields have doubled (from 19.2 to 39.3 bushels per acre) in the four decades from 1935 to 1975. Improvements in culture technologies such as fertilizers, pesticides, and machinery accounted for about 50 percent of the increase and genetic improvements accounted for the other 50 percent.

- Some technologies depreciate more rapidly than others. Technologies developed for the control of insects and diseases are especially prone to rapid depreciation and obsolescence. Nature's propensity for new genetic combinations, combined with prolific reproduction and heavy selection pressure, can cause rapid change in the genetic composition of the resultant pest population. When that occurs, control technologies must be updated or replaced.

Meeting Unforeseen Threats

Unforeseen events that may arise and threaten food, fiber, and forest-product technologies fall into three major categories: natural disasters, food and environmental safety concerns, and control of insect and disease pests.

• Soon after the eruption of Mount St. Helens in Washington State on May 18, 1980, agricultural experiment stations, cooperative extension services, and the Agricultural Research Service and Forest Service of USDA responded to public concerns over the ash deposits. Information was gathered from all sources, chemical and physical analyses of the ash were conducted, and solutions to help alleviate the problems caused by the eruption were recommended. Products such as timber were salvaged, and the adverse effects on crops and livestock were minimized.

• Food and feed supplies may be contaminated by accident or by naturally occurring toxins. Guarding against contamination requires human resources who are familiar with agriculture, biology, and chemistry, and who have access to the analytical instruments to provide constant vigilance.

• The devastating impact of insects and disease on man's food supply is as old as recorded history. Swarms of locust and epidemics like the Irish potato blight remain a haunting specter. Agriculture has an arsenal of technologies to help combat insect and disease pests. The enemy is always time. One reason that U.S. agriculture has been so effective in combating pests is because the knowledgeable scientists and extension specialists who are working on these problems are dispersed across all crop and forest regions.

The base required to maintain and improve current technologies and meet unforeseen threats is proportional to the level of the technology. As a technology becomes more complex and specific, more scientists and technicians are required. In agriculture, the complexity is enormous, requiring knowledge and skills in many individual subject-matter areas, and knowledge of the interactions when several technologies are combined into a production system.

E. Equipment and Facilities

Scientists in publicly supported institutions have traditionally provided most of the new research ideas and innovative leadership in science, which in turn has stimulated industrial technology and business development and advanced the frontiers of knowledge for our society. However, the equipment and facilities needed to support this research and leadership are becoming progressively more sophisticated and, therefore, expensive. In addition, recent reports have underscored the problem of obsolescence of scientific instruments in publicly supported laboratories for basic research and the concomitant reduction in support for purchase or renovation of instruments. The need for new or improved facilities presents a quite different situation, but is related to the housing and effective use of the instrumentation.

Instrumentation—Needs and Maintenance

Instrumentation will be needed for two major purposes: (1) to conduct research and (2) to train people. These needs will be nearly identical for graduate student training, while the level of instrumentation-sophistication needed for undergraduate training will usually be less. Future projections about instrumentation must also consider the

acute problem of securing trained personnel to operate and maintain the more complex instrumentation, whether for research or teaching.

In the American Association of Universities report (1982) to the National Science Foundation, the investigating committee reported that support facilities of government laboratories surpassed those of university labs, and the best industrial labs surpassed, to a startling degree, all aspects of research support seen at university labs. Scientists who were principal investigators on grants responded to a questionnaire (Dr. M. Berliner, NSF study entitled "Status of Research Instrumentation in the Plant Sciences," June 1982) that their most urgent need was the replacement of equipment bought 15 to 25 years ago. Repair, maintenance, and updating were next in order of priority.

With the shrinking dollars available for purchase and maintenance of instrumentation, investigators report an increasing need to seek support from multiple sources simply to maintain a constant level of activity in research projects. This effort is costly because large amounts of time and ingenuity are expended in writing the multiple grants, thus diverting valuable time from research.

Instrumentation needed for basic research over the next 20 to 30 years will often be built upon some of the same principles as those in current use, but the practical details and modifications to increase resolution and efficiency may change decisively as the state of the art advances. For example, plasmid DNA can be spun down in an ultracentrifuge with the new vertical rotor in 4 hours; previously it required 48 hours or longer. Such time savings not only expedite the research but increase dramatically the life of the ultracentrifuge. New, unique instruments also will be invented, some combining principles from several technologies—lasers, fluorescence spectrometry, and computer automation, for example. The reference document contains a list of anticipated equipment needs for a modern molecular biology lab. To be properly equipped requires a significant investment.

Facilities—Needs and Maintenance

The Joint Council on Food and Agricultural Science, in their January 1981 Report to the Secretary of Agriculture, indicated that USDA research facilities had space for 647 additional scientist years (SY). State land-grant institutions had an overall deficit of 965 SY's of office and laboratory space. Unfortunately, surplus space in federal facilities does not easily lend itself to meeting space needs of the states because of differing geographical location and because of limitations in the design of the facilities for which the research was intended. Often the surplus space would require expensive renovations in order to fit the space needs of other federal research programs. Despite these difficulties, analysts of this situation see more opportunities for sharing that should be pursued.

New communications systems make distances less important. Distances between research, extension, and teaching facilities no longer affect programs as they would have 30 years ago. In the future, geography will probably become less significant, with the exception of field and environment testing.

Repairs and maintenance in publicly owned research facilities are not always up to date with respect to OSHA standards, other federal and state standards, and standards found in private institutions. Inadequate operating funds at many locations have led to neglect of proper maintenance and timely repair, resulting in deteriorating of existing facilities. Renovation needs for both federal and state facilities are substantial. Federal programs required renovation for 820.7 SY's or 18.4 percent of their 1978 scientific population. State programs required renovation for 1249.5 SY's or 18.7 percent of their 1978 scientific population.

V. Performers of Research, Extension, and Higher Education

Most descriptions of publicly supported science and education programs in agriculture focus on the USDA, land-grant universities, and others. Although useful as a preliminary introduction, such descriptions fail to capture both the numerous ways in which these segments interact and the emerging importance of non-land-grant colleges and universities and the private sector (Feller et al., 1983). The "performers" of public agricultural research and education are located in state and federal institutions with varying administrative and program structures. Each institution or agency has a specific role. Interaction among "performers" grows out of program linkages and coordination developed through cooperative planning and shared institutional processes. This informal set of linkages provides for communication among scientists and promotes developments that have helped establish a system-wide approach in research, extension, and higher education. State-managed science and education programs must and do respond to needs expressed at state and local levels, but they also address regional, national, and international issues because of the implications these issues have for the local agriculture industry. The federally-managed science and education programs are directed primarily at regional, national, and international issues, but the findings often have implications at state and local levels, where producers and consumers make their individual decisions.

A. Research

Land-grant performers include 56 Agricultural Experiment Stations (including Departments of Forestry, Colleges of Veterinary Medicine, and Home Economics). In addition there are 16 separate schools of forestry, Tuskegee Institute, and 16 of the 1890 colleges. The USDA provides support, reviews, and national coordination for these state-managed programs through the Cooperative State Research Service. The main internal performers of research in USDA are the Agricultural Research Service, Forest Service, and Economic Research Service. The Office of International Cooperation and Development has the responsibility for coordinating the Department's international science programs.

The related research efforts occurring in other federal agencies are, in general, being done for different purposes than the research conducted by state Agricultural Experiment Stations and USDA. A relationship exists because there are interlocking interests

and the research often depends on similar scientific disciplines, i.e., biology, chemistry, and economics. When the National Institutes of Health fund a study in human diseases, Colleges of Veterinary Medicine often have a strong mutual interest. When the Fish and Wildlife Service investigates population trends of endangered species, the habitat conditions existing on farms are often an important causal element. About 65 percent of the agriculture-related research funded by non-USDA federal agencies is conducted through contracts and grants with private firms, universities, and other institutions. The remaining work is conducted in federally operated laboratories. A more complete analysis of these activities is available in a report prepared by USDA (March 1982) entitled "Inventory of Research, Extension, and Higher Education related to Food and Agriculture, conducted by Federal agencies other than USDA."

The non-land-grant public university system consists of more than 350 state colleges and universities. Of this group, approximately 65 have programs in agriculture and forestry. The primary mission of these colleges and universities is the provision of undergraduate and master's level education. Reported research activity for agriculture-related programs amounted to $14 million in the 1980-81 academic year. Most of the funds came from non-USDA federal agencies, industry, and state governments.

By far the largest segment of the overall food, fiber, and forestry research and development (R & D) system is the private sector. This sector's activities are poorly documented, but recent surveys have developed expenditure estimates and discussed the nature of the research. In 1979, the National Science Foundation estimated private-sector R & D expenditures at $1.8 billion. A more recent estimate puts it at $2.5 billion. By their own admission, managers of private-sector R & D emphasize product or market-oriented studies. At the farming level, 75 percent of the R & D expenditures are for pesticides, drugs, and farm equipment—areas of unique concern to suppliers of farm production inputs. At the post-farming level, the emphasis is on food processing, machinery, and packaging. In general, industry performers have little motivation for expending R & D resources on either natural resource and environmental issues or to better understand basic biological processes. They generally depend on public-sponsored research for this information. Unless R & D results can be patented and used in a company product fairly quickly, private companies are reluctant to finance scientific studies.

One example of the motivating force of patents is the expanding interest of the private sector in genetic engineering. Since altered organisms can now be patented, both small and large companies are expanding their R & D efforts in this area. Several joint ventures are either underway or being planned between universities and private companies.

Research Funds by Source

State Agricultural Experiment Stations (1982)[1]	*Amount (Mil)*
USDA Funding	
Hatch and McIntire-Stennis	174.6
Grants and Contracts	39.5
Other	5.7
Total USDA	214.8
Other Federal Grants and Contracts	122.0
Total Federal	341.8
State Support[2]	714.6
Total Federal and State	1,056.4
USDA Performers (1983)[1]	
Agricultural Research Service	454.4
Forest Service	105.0[3]
Economic Research Service	38.9[3]
Office of International Cooperation & Development	3.3
Others	20.2
Total	621.8
Related Efforts in Other Federal Agencies (1981)[1]	
National Oceanic & Atmospheric Administration	72.4
National Institutes of Health	173.4
Interior (Primarily Geological Survey, Fish and Wildlife Service, and Bureau of Reclamation)	106.9
National Science Foundation	24.5
Tennessee Valley Authority	19.5
Others	124.1
Total	520.8[4]

[1]Indicates year of funding.

[2]Includes state appropriations (primary source), sales of products, and industry grants and contracts.

[3]Represents research-related part of agency budget.

[4]The $122.0 million shown for state Agricultural Experiment Stations is included in this figure.

B. Extension

Cooperative Extension was designed as a partnership of USDA and the land-grant universities. State legislation enabled local governments or organized groups in the Nation's counties to become a third partner in this educational endeavor. There are professional extension staff in nearly all of the Nation's 3,150 counties. In addition, 1 1/2 million volunteer leaders work with the full-time personnel. At the national level, 100 professionals within USDA direct federal fund allocations, coordinate National initiatives, and provide program leadership. The partners in Cooperative Extension are interdependent, yet each has considerable autonomy in funding, staffing, and programming. The system is characterized by two-way communications between those who work for Extension and those who use the information; thus, researchers and educators have an early awareness of problems.

In addition to the educational programs of the Extension Service, other USDA agencies perform informational and technology-transfer activities. These include the Soil Conservation Service, Forest Service, Food and Nutrition Service, and others. These information transfer activities are integral parts of those agencies' missions and thus are not separate budget items. At the county, state, and national level there are active coordination efforts between these agencies and the Extension Service. Similar coordination exists with non-USDA federal agencies that have information/extension type programs.

The level of extension-related information activities in the private sector is not known. This lack of data, however, should not be construed to mean that these activities are insignificant. An important component of selling any product is educating the buyer on its proper use and the expected benefits. Many manufacturers, processors, and distributors maintain a close, cooperative relationship with agricultural research and extension workers. A similar relationship exists with private consultants who sell their services to agricultural and forest landowners and managers. This synergistic relationship is viewed now, and for the future, as appropriate and beneficial to all parties involved—particularly to the consumers of the final product.

C. Higher Education

At least 136 U.S. universities and colleges offer degree programs in the food and agricultural sciences. A little more than half of these institutions are land-grant schools. Most of the non-land-grant schools are publicly supported, but are not direct partners with the Department of Agriculture. The number of graduates in agriculture-related sciences in 1981 were: 28,665—bachelor's; 5,503—master's; and 1,039—Ph.D's. Based on data from the Department of Education's National Center for Education Statistics, these totals reflect the following specialty areas: veterinary medicine, agriculture and natural resources, human nutrition, plant pathology, and agricultural engineering. At the bachelor's level the split between land-grant and non-land-grant institutions is 62.5 percent and 37.5 percent respectively. At the master's level it is 67.0 percent and 33.0 percent. Most Ph.D degrees in agriculture-related sciences are granted by land-grant institutions.

Extension Funds by Source

Cooperative Extension (1983)[1]	Amount (mil)
USDA Support	
Smith-Lever, 1890's, & Tuskegee	259.8
Food and Nutrition Education	60.4
Other	3.0
Total USDA	323.2
State	388.0
County	161.9
Non-Tax Source	27.1
Total (Federal, State, County	900.2

Related Extension Efforts in Other Fed. Agencies (1981)[1]	
Energy Department	20.3
Labor Department	11.8
Tennessee Valley Authority	14.8
Others	13.5
Total	60.4

[1]Indicates year of funding

Major financial support for higher education in agriculture, particularly at the undergraduate level, comes from state governments. In public universities, faculty compensation is often established by the legislatures or negotiated between the state government and the university. Articulation of public university roles within a state is also an important role of state government; that is, which universities will offer what kind of agricultural education. Development of agricultural curricula and the granting of degrees remains the province of the individual institutions, and accreditation is provided by regional and national associations.

Including cost of instruction, academic services, and maintenance and operation of the physical plant, institutions of higher education spend close to *$1 billion* each year to train people in agriculture and natural resources. This estimate includes tuition contributions of students but no other student expenses (e.g., books, room, and board). This amount represents a considerable commitment by residents of the states to provide a trained pool of professionals that make contributions at local, state, and national levels of the economy.

D. Why Public Investment?

The primary reason for public investment in agricultural science and education programs has been that, in many areas, *incentives for the private sector are inadequate* (Ruttan, 1982). The rationale for this statement is based on the difference between private and public goods (Mueller, 1979).

Characteristics of Private Goods

When a private firm can capture most or all the value of a good in the marketplace, it has the incentive to produce and distribute the amount demanded at a market clearing price. For goods such as bread, cars, and television sets, the purchaser has exclusive use of the benefits. In addition, the value is not shared by someone outside the immediate household. A similar condition exists when a private firm develops and sells an improved pesticide, animal vaccine, or piece of farm equipment and is able to protect the value of that improved technology with a patent. The farmer who purchases this item has exclusive use of the improved product and there are little or no benefits, derived from its use, shared with other farmers. In both of these situations the exchange of value is, to a major degree, within the control of the producer and consumer of the good. To be considered a private good, that is a necessary condition.

Characteristics of Public Goods

For public goods like national defense, environmental concerns, and major portions of agricultural science and education programs, the performers and users cannot feasibly withhold the benefits from others. In other words, those who do not purchase or pay for any of the public or collective goods cannot be excluded or kept from sharing in their consumption. For example, a person paying no federal taxes is protected from a foreign enemy just as well as a person who does pay taxes. A beautiful mountain scene can be enjoyed both by a passerby and by the landowner who protects its natural character. The contribution of a trained scientist, in agronomy for example, cannot possibly be captured fully by sellers and buyers in the marketplace. The benefits derived from developing improved farming practices (that increase plant output per acre and conserve soil resources) serve future generations as well as today's. When scientists transmit the nature of those improved agronomic practices to the next generation of scientists and managers, another benefit is being realized.

There are obviously different degrees of public and private goods. The above examples are at opposite ends of a continuum. However, when a good tends toward being more public than private, the need for public investment becomes more obvious. When a good has more characteristics of a private good, it should be left to the forces of the marketplace. *In the mixed economic system that exists in the United States, both public and private performers must carry out their respective functions or the total society suffers.*

Returns on Investments

When describing the theoretical foundation of public goods, Samuelson (1959) stated "No decentralized pricing system can serve to determine optimally those levels of collective actions." This conclusion is especially appropriate when it comes to investment in scientific programs. Evenson, Waggoner, and Ruttan (1979) have shown significant returns for past public investments in agricultural research and education—from 45 to 130 percent—the kind of returns private business would relish. These figures provide strong evidence for the public nature of these investments. *If the benefits could have been captured by a private performer, those kinds of returns would have attracted private funds.*

The split between public and private investment in future scientific programs will differ somewhat from the past. Changes in patent laws (the 1980 Chakrabarty decision opened up the opportunity to patent living organisms), increasing size of commercial farms, and increased dependence of farming on industrially produced inputs all affect the publicness and privateness of research and education programs in agriculture (Evenson, 1983).

References Cited

Barlowe, Raleigh. *Land Resource Economics: The Economics of Real Property*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1972.

Boyer, John S. "Plant Productivity and Environment," *Science* 218:443, American Association for the Advancement of Science, Washington, D.C., 1982.

Christensen, Lee A. *Water Quality: A Multidisciplinary Perspective*, published for North Central Committee III: Natural Resource Use and Environmental Policy, by the Soil Conservation Society of America, Ankeny, Iowa, 1983.

Council of Agricultural Science and Technology. *The Emerging Economics of Agriculture: Review and Policy Options*, Report No. 98, Ames, Iowa, September 1983.

Cox, Meg. "Cows on Midwest Farm Get Automatic Reward for Giving More Milk," *The Wall Street Journal*, Washington, D.C., September 21, 1983.

Crossan, Pierre R. and Sterling Brubaker. *Resource and Environmental Effects of U.S. Agriculture*. Resources for the Future, Washington, D.C., 1982.

Evenson, Robert E., Paul E. Waggoner, and Vernon W. Ruttan. "Economic Benefits from Research: An Example from Agriculture," *Science*, 205, American Association for the Advancement of Science, Washington, D.C., September 1979.

Frederick, Kenneth D. "Irrigation and the Future of American Agriculture" in *The Future of American Agriculture as a Strategic Resource*, Sandra S. Batie and R. G. Healy, eds., The Conservation Foundation, Washington, D.C., 1980.

Halerow, Harold G., Earl O. Heady, Melvin L. Cotner, editors. *Soil Conservation Policies, Institutions, and Incentives*, published for North Central Research Committee III: Natural Resource Use and Environmental Policy, by the Soil Conservation Society of America, Ankeny, Iowa, 1982.

Hansel, William. "Future Agricultural Technology and Resource Conservation: Beef and Dairy Cattle, Sheep, Goats, Swine and Poultry," paper presented at the RCA Symposium: Future Agricultural Technology and Resource Conservation, Washington, D.C., December 1982.

Mueller, Dennis C. *Public Choice*, Cambridge University Press, New York, 1979.

National Association of State Universities and Land-Grant Colleges, Division of Agriculture Committee on Biotechnology. *Emerging Biotechnologies in Agriculture: Issues and Policies*, Progress Report, Washington, D.C., November 1982.

57-279 O - 87 - 31

Ruttan, Vernon W. *Agricultural Research Policy,* University of Minnesota Press, Minneapolis, Minnesota, 1982.

Ruttan, Vernon W. "Changing Role of Public and Private Sectors in Agricultural Research," *Science,* Vol. 216, April 2, 1982.

Sundquist, W. Burt. "Technology and Productivity Policies for the Future," *The Farm and Food System in Transition: Emerging Policy Issues,* FS 4, paper sponsored by the Extension Committee on Organization and Policy, USDA-Extension, published by Cooperative Extension Service, Michigan State University, East Lansing, Michigan, 1983.

Thurow, Lester C. "Farms: A Policy Success," in *Newsweek,* New York, New York, May 16, 1983.

U.S. Congress, Office of Technology Assessment. *Wood Use: U.S. Competitiveness and Technology,* OTA-ITE-210, Washington, D.C., August 1983.

U.S. Department of Agriculture, Science and Education. *Inventory of Research, Extension, and Higher Education Related to Food and Agriculture Conducted by Federal Agencies Other Than USDA,* Policy Analysis and Coordination Staff, Washington, D.C., March 1982.

U.S. Department of Agriculture, Soil Conservation Service. *National Conservation Technical Assistance Targeting Plan, Fiscal Years 1983-87,* National Headquarters, Washington, D.C., April 1983.

Walker, David J., and Douglas L. Young. "Technical Progress in Yields—No Substitute for Soil Conservation," published in Current Information Series No. 671, College of Agriculture, University of Idaho, Moscow, Idaho, 1983.

Wittwer, Sylvan. "New Technology, Agricultural Productivity, and Conservation," in *Soil Conservation Policies, Institutions, and Incentives,* published for North Central Research Committee III: Natural Resource Use and Environmental Policy, by the Soil Conservation Society of America, Ankeny, Iowa, 1982.

Appendix A
Country/Region Coverage

North Africa/Middle East	—The northern tier of the African countries, and the Middle Eastern countries, including Turkey and Afghanistan.
Sub-Saharan Africa	—All the countries of Africa (including South Africa) except the northern tier (Algeria, Egypt, Libya, Morocco, and Tunisia) which are in North Africa/ Middle East.
EEC-10	—The member countries of the European Economic Community.
Other Western Europe	—The Western European countries who are not members of the European Economic Community.
USSR	—A single-country region.
Eastern Europe	—All of the Eastern European countries, including Yugoslavia.
South Asia	—Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka.
East Asia	—Japan, Brunei, Burma, East Timor, Hong Kong, Indonesia, Republic of Korea, Laos, Macau, Malaysia, Maldives, Philippines, Singapore, and Thailand.
Asian Centrally Planned Economies	—China (including Taiwan), Kampuchea, Democratic People's Republic of Korea, Mongolia, and Vietnam.
Oceania	—Australia, New Zealand, and the other islands of Oceania.
Latin America	—Mexico and all the other Central and South American countries.
North America	—The United States and Canada.

Appendix B
Source Documents

I. Needs Assessment Reference Document

A. Introduction
W. Joseph Lanham, Needs Assessment Task Group and Program Leader, Economic Development, ES/USDA.

B. Overview of Long-Term Needs for Food, Fiber, and Forest Products
Kenneth R. Farrell, Fred H. Sanderson, Trang T. Vo, and Michael F. Brewer, Resources for the Future, Washington, D.C.

C. Long-Term Problems and How Science and Education Can Impact Those Problems
Soil, Water, and Air Resources—Albert R. Grable, National Program Leader, ARS/USDA; and William E. Larson, Head, Department of Soil Science, University of Minnesota.

Forest, Range, and Wildlife—Richard A. Skok, Dean, College of Forestry, University of Minnesota; Elwood L. Shafer, Staff Assistant to the Deputy Chief for Research, FS/USDA; Gale Wolters, Range Scientist, FS/USDA; and James E. Miller, Program Leader, Fish and Wildlife, ES/USDA.

Crop Production and Protection—John S. Boyer, ARS/USDA, University of Illinois; and John P. Mahlstede, Assoc. Dean, College of Agriculture, Iowa State University of Science and Technology.

Animal Production and Protection—Terry Crawford, ERS/USDA; Terrence M. Curtin, Dean, College of Veterinary Medicine, North Carolina State University; Sheila Gillette, Needs Assessment Task Group, ARS/USDA; Dixon Hubbard, Program Leader, Animal Sciences, ES/USDA; Bernard Jones, Dean and Director, College of Agriculture, University of Nevada; Dyarl King. ARS/USDA; Robert Oltjen, U.S. Meat Animal Research Center, Clay Center, Nebraska; and Walter Woods, Head, Dept. of Animal Sciences, Purdue University.

Processing, Marketing, and Distribution—Leo Polopolus, Chm., Dept. of Food and Resource Economics, University of Florida; Arnold E. Denton, Vice President, Research and Technology, Campbell Soup Co.; Harold S. Ricker, Deputy Director, Market Research and Development Div., AMS/USDA.

Human Nutrition—Patricia B. Swan, Professor, Dept. of Food Science and Nutrition, University of Minnesota; and Robert O. Nesheim, Vice President, Science and Technology, Research, and Quality Assurance, Cambridge Plan International, Monterey, California.

Family and Consumer Programs—Katherine S. Tippett, Family Economics Research Group, ARS/USDA; and Jane L. McCullough, Dept. of Home Economics and Consumer Education, Utah State University.

Youth, Family, and Community Development—W. Robert Lovan, National Program Coordinator, Community Decision Making Structures, ERS&ES/USDA; Adger B. Carroll, Asst. Director of Cooperative Extension Service, Natural Resources and Public Policy Programs, Michigan State University; and W. Joseph Lanham, Needs Assessment Task Group and Program Leader, Economic Development, ES/USDA.

Agricultural Policy—Kenneth C. Clayton, Director, National Economics Div., ERS/USDA; and Bruce W. Gardner, Professor, Dept. of Agricultural Economics, University of Maryland.

International—Ernest L. Corley, Acting Senior Deputy Administrator, OICD/USDA.

D. Needs of Science and Education System To Continue Solving Problems of U.S. Agriculture

Developing Scientific Expertise in Agriculture—Kenneth W. Reisch, Assoc. Dean, College of Agriculture and Home Economics, Ohio State University; Allan D. Goecker, Asst. Dean, School of Agriculture, Purdue University; and Geri C. Richmond, Needs Assessment Task Group, and Management Analyst, OGPS/USDA.

Biotechnology in Agriculture—New Tools for the Oldest Science—Alice F. Skelsey, President, WRD Associates, Inc., Annandale, Virginia, with the aid of a group of scientists.

Information Systems and Communications Technology—Jane Roth, Needs Assessment Task Group and Program Analyst, OGPS/USDA; Tom Tate, Program Analyst, ES/USDA; and Sam Waters, Assoc. Director of National Agricultural Library.

Scientific Requirements for Maintaining Technology and Developing Human Capital—Charles B. Rumburg, Needs Assessment Task Group, Plant and Animal Science, CSRS/USDA.

Equipment and Facilities—Larry W. Moore, Assoc. Professor of Plant Pathology, Dept. of Botany and Plant Pathology, Oregon State University; and W. Joseph Lanham, Needs Assessment Task Group and Program Leader, Economic Development, ES/USDA.

II. Science and Education Planning Documents

Agricultural Research Service Strategic Plan, ARS/USDA. 1983

Extension in the '80's, CES in cooperation with USDA/NASULGC. 1983

Challenge and Change . . . A Blueprint for the Future, ES/USDA. 1983

RCA Symposium: Future Agricultural Technology and Resource Conservation. SCS, USDA. 1983.

Draft documents for the 1985 Resource Conservation Act, SCS/USDA

Draft documents for the 1985 Resource Planning Act, FS/USDA

Agricultural Research, Extension, and Education Recommendations Report, User Advisory Board. 1983

Human Capital Shortages: A Threat to American Agriculture, RICOP/NASULGC. 1983

Report of White House Science Council's Federal Laboratory Review Panel. 1983

Agriculture 2000, Batelle Memorial Institute. 1983

U.S. Agricultural Capacity and Utilization, ERS/USDA. 1983

The Changing Structure of South Dakota Agriculture. 1983

Delaware Agriculture in the 1980's: Future Direction. 1983

Emerging Biotechnologies in Agriculture: Issues and Policies, NASULGC. 1982 and 1983

The Farm and Food System in Transition, ECOP, ES/USDA, CES. 1983

1980-90 National Program of Research for Forests and Associated Rangeland, FS/USDA. 1982

Human Nutrition Research, Training and Education Update for the 1980's. 1982

National Agricultural Library Strategic Plan. 1982

Human Capital: The Ultimate Resource. 1982

Rural Governments in a Time of Change: Challenges and Opportunities, USDA and Rural Governments Coalition. 1982

Oklahoma Agriculture 2000, Oklahoma State University. 1982

Food—From Farm to Table, Yearbook of Agriculture, USDA. 1982

Soil and Water Resources: Research Priorities for the Nation. 1982

A Comprehensive National Plan for New Initiatives in Home Economics. 1981

Graduates of Higher Education in the Food and Agricultural Sciences: An Analysis of Supply-Demand Relationships, USDA. 1981.

Appendix C
Joint Council on Food and Agricultural Sciences Membership List

ANDERSON, James H. (Cochair)*
Dean, College of Agriculture & Natural Resources
Michigan State University
East Lansing, MI 48824

BENTLEY, Orville G. (Cochair)*
Assistant Secretary
Science and Education
U.S. Department of Agriculture
Room 217-W, Administration Building
Washington, D.C. 20250

BUCKMAN, Robert E.
Deputy Chief for Research
Forest Service, USDA
Rm. 3007, South Building
Washington, D.C. 20250

CORLEY, Ernest L.
Acting Senior Deputy Administrator
Office of International Cooperation and Development
U.S. Dept. of Agriculture
Rm. 3059, South Building
Washington, D.C. 20250

COULTER, K. Jane
Director, Higher Education Programs
Agricultural Research Service, USDA
Rm. 323-A, Administration Building
Washington, D.C. 20250

EDWARDS, Jeanne
Users Advisory Board Representative
240 Westerly Road
Weston, MA 02193

GREENWOOD, Mary Nell
Administrator, Extension Service
U.S. Department of Agriculture
Rm. 340-A, Administration Building
Washington, D.C. 20250

HAWTHORNE, Betty E.
Dean, College of Home Economics
Oregon State University
Corvallis, OR 97331

HILDRETH, R. J.
Managing Director
Farm Foundation
1211 W. 22nd Street
Oak Brook, IL 60521

HOWARD, Joseph H.
Director
National Agricultural Library
U.S. Department of Agriculture
Rm. 109-A, NAL Building
Beltsville, MD 20705

HUGHES, Jay M.*
Dean of the College of Forestry and Natural Resources
Colorado State University
Fort Collins, CO 80523

HURST, Robert L.
Vice President for Research and Extension
South Carolina State College
P.O. Box 1765
Orangeburg, SC 29117

JOHNS, Dawson M.
Emeritus Resident Director and Professor
Louisiana State University
P.O. Box 127
Homer, LA 71040

JORDAN, John P.
Administrator, Cooperative State Research Service
U.S. Department of Agriculture
Rm. 322-A, Administration Building
Washington, D.C. 20250

KENDRICK, Edgar L.
Director, Office of Grants and Program Systems
U.S. Department of Agriculture
Rm. 217-W, Administration Building
Washington, D.C. 20250

KINNEY, Terry B.
Administrator, Agricultural Research Service, USDA
Rm. 302-A, Administration Building
Washington, D.C. 20250

KLEIS, Robert W.
Dean & Director, International Programs Division
University of Nebraska-Lincoln
210 Ag Hall
Lincoln, NE 68583

LEE, John E.*
Administrator, Economic Research Service, USDA
Rm. 448, GHI Building
500 12th Street, S.W.
Washington, D.C. 20250

LITTLE, C. Oran
Associate Director
Experiment Station
University of Kentucky
Lexington, KY 40546-0091

LUCK, John V.
Senior Vice President
General Mills, Incorporated
James Ford Bell Technical Center
9000 Plymouth Avenue North
Minneapolis, MN 55427

LUND, H. Roald
Dir., Agricultural Experiment Station
North Dakota State University
Box 5435, State University Station
Fargo, ND 58105

MOLINE, W. J.*
Dir., Cooperative Extension Service
University of Arkansas
P.O. Box 391
Little Rock, AR 72203

OWEN, Robert R.
President, The Eversman Mfg. Co.
1145 Fifth Street
P.O. Box 4345
Denver, CO 80204

PETTIBONE, C. Alan
Associate Dean
College of Agriculture
Washington State University
Pullman, WA 99164

SHIMEL, William A.
Director, Extension Service
Morrill Hall
University of Vermont
Burlington, VT 05405

SLEDGE, George W.
Associate Dean & Director
Academic Affairs, College of Agricultural & Life Sciences
University of Wisconsin
Madison, WI 53706

SMALLWOOD, Charles M.*
Dean, School of Agriculture and Home Economics
California State University
Fresno, CA 93740

STRATTON, Louie G.
Director, Veterinary Medicine Teaching Hospital
College of Veterinary Medicine
Oklahoma State University
Stillwater, OK 74078

WALLACE, GORDON D.
Senior Policy Analyst
Office of Science & Technology Policy
New Executive Office Building
Washington, D.C. 20500

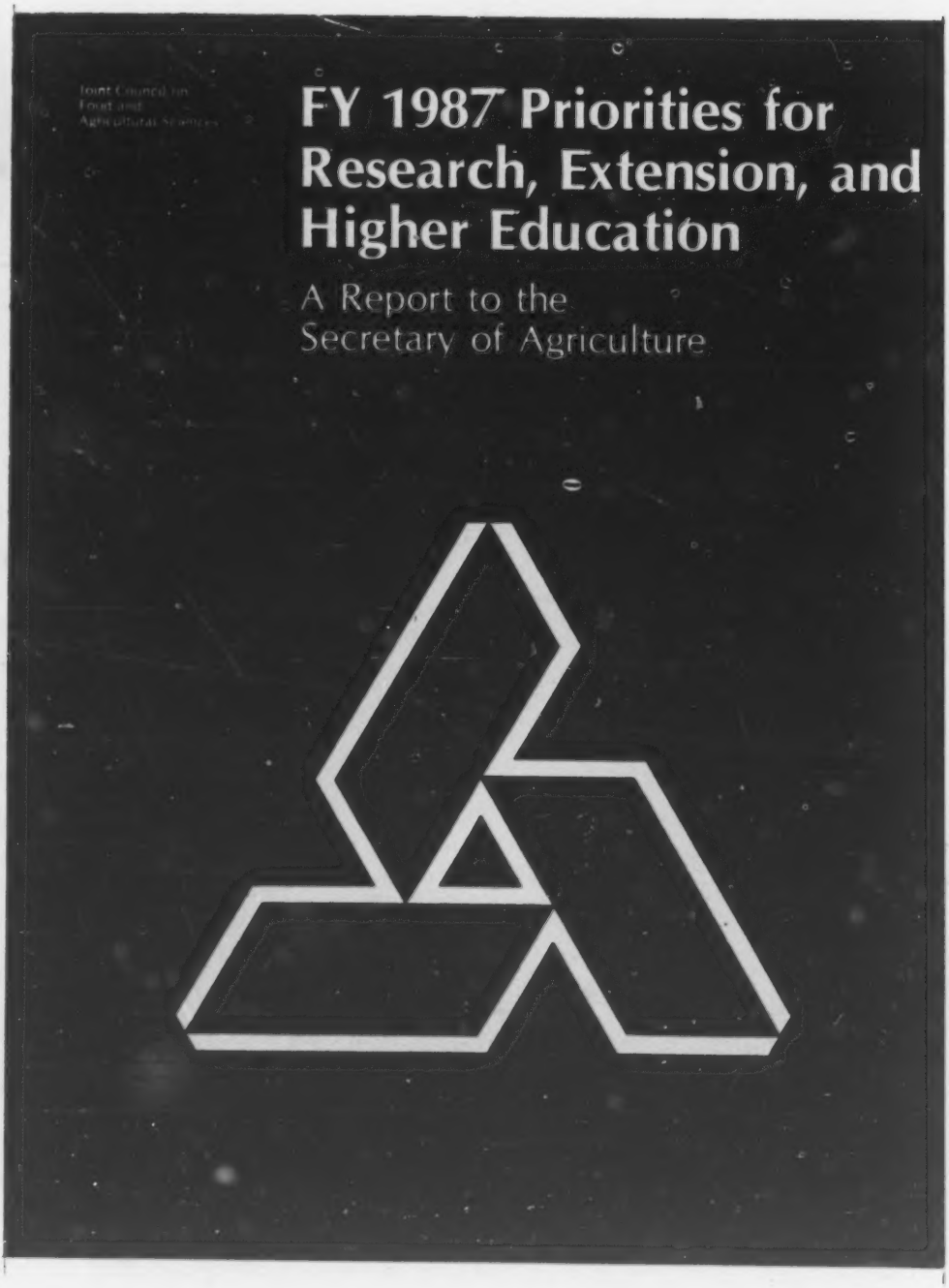
WEFALD, Jon
Chancellor
Minnesota State University System
230 Park Office Building
555 Park Street
St. Paul, MN 55103

WILLIAMSON, Handy
Director, Cooperative Agricultural
Research Program
Tennessee State University
P.O. Box 522
Nashville, TN 37203

Executive Secretary to the Joint Council.

MILLER, Larry R.
Joint Council on Food and Agricultural
Sciences
U.S. Department of Agriculture
Rm. 350-A, Administration Building
Washington, D.C. 20250
(202) 447-8662

*Member of the Executive Committee


Joint Council on
Food and
Agricultural Sciences
FY 1987 Priorities for
Research, Extension, and
Higher Education
A Report to the
Secretary of Agriculture

The Joint Council on the Food and Agricultural Sciences was established in 1977 to encourage and coordinate research, extension, and higher education activities in the food and agricultural sciences. This role was strengthened in the Agriculture and Food Act of 1981, which directed the Department to improve the planning and coordination of research, extension, and higher education within the public and private sectors and to relate the federal budget process to the overall functioning of the system.

The Joint Council initiated four reports intended to improve the overall effectiveness of the food and agricultural system.

A long-term **needs assessment** (20-30 years) for food, fiber, and forest products and the research, extension, and higher education requirements to meet the identified needs. (This task was assigned to the Secretary of Agriculture in the Agriculture and Food Act of 1981. He requested the Joint Council to fulfill this responsibility). The needs assessment report was prepared and published in two separate documents. One is the *Reference Document: Needs Assessment for the Food and Agricultural Sciences* and the other is the *Summary: Needs Assessment for the Food and Agricultural Sciences.*

A **five-year plan** to reflect the coordinated goals and objectives of the research, extension, and higher education community. This report was published in 1984 and will be updated biannually.

An **annual priorities report** on research, extension, and higher education, which presents the Joint Council's priorities for the next fiscal year, the required financial support, and suggested federal, state, and private sector roles. This report will be completed by June 30 of each year.

An **annual accomplishments report** which specifies the ongoing research, extension, and higher education programs and respective accomplishments, along with expectations for the future. This report will be completed by November 30 of each year.

These four reports are inter-related although each is published separately. They constitute an overall strategic planning process which provides the food and agricultural science system with a means of assessing short-term and long-term future needs and reflecting on past accomplishments. They provide a foundation for planning the most effective and efficient means for meeting the future demands for food, fiber, and forest products. These four reports also offer a continuing mechanism by which the research, extension, and higher education programs can assess future needs.

The symbol appearing on the front cover represents the purpose of the Joint Council (i.e., to improve planning and coordination among research, extension, and higher education) and the cooperative character of the food and agricultural science system within federal, state, and private organizations.

Joint Council on Food and Agricultural Sciences

Secretariat:
Rm. 321 A, Admin. Bldg.
U.S. Department of Agriculture
Washington, D.C. 20250

June 28, 1985

Honorable John R. Block
Secretary of Agriculture
Washington, D.C. 20250

Dear Mr. Secretary:

We are pleased to submit the annual priorities report on research, extension, and higher education, prepared by the Joint Council on Food and Agricultural Sciences in accordance with Title XIV of the Agriculture and Food Act of 1981 (Public Law 97-98).

The Joint Council prepared this report after considering 86 priorities submitted by the National Committees and Regional Councils of the Joint Council.

We have selected five science and education areas to be emphasized as budget plans are developed for fiscal year 1987. In order of priority, they are:

1. Increase Agricultural Profitability Through Management
2. Improve Water Quality and Management
3. Expand Biotechnology Efforts on Plants, Animals, and Microbes
4. Develop Necessary Scientific and Professional Human Capital
5. Improve Human Nutrition and Understanding of Diet/Health Relationships

While it is important to focus on these key areas in FY 1987, continued funding for the base programs in research, extension, and teaching must also be emphasized. Significant and special thrusts in the key priority areas, along with strong base programs, will assure the continued technological progress necessary for a strong, healthy agriculture.

Sincerely,

Orville G. Bentley
ORVILLE G. BENTLEY
Cochairman

James H. Anderson
JAMES H. ANDERSON
Cochairman

Enclosure

FY 1987 Priorities for Research, Extension, and Higher Education

A Report to the
Secretary of Agriculture

CONTENTS

		Page
	Executive Summary	iii
I.	Introduction	1
II.	Selecting the National Priorities	3
III.	Recommended National Priorities	7
IV.	Financial Support Needed for Priority Programs	15

Appendices

1.	Priorities Recommended by the National Research, Extension, and Higher Education Committees, Regional Councils and Committees	17
2.	Other Important Priorities	23
3.	Joint Council Membership List	41
4.	References	43

This report was prepared by the Joint Council Reports Staff:

Timothy H. Blosser, ARS, Leader
Kenneth P. Dorschner, CSRS
Gary C. Taylor, ERS
Roger Wilkowske, ES

Typing was done by Adrienne P. Baylor, OGPS

Research, extension, and higher education programs in food and agriculture have important roles in shaping the future of both U.S. and world food, fiber, and forest product supplies. Continuous planning, both short- and long-term, is necessary if we are to use resources most efficiently and effectively. The Joint Council on Food and Agricultural Sciences has a congressionally-mandated role to develop plans for the future. The Council prepares the annual Priorities Report as a guide for those who develop the federal budget and for others in science and education who seek guidance concerning important national problems currently facing the food and agricultural system. A longer term look at the most urgent problems needing solution is presented in the Joint Council Five-Year Plan.

In developing the FY 1987 Priorities Report, the Joint Council requested and received from the National Agricultural Research Committee, the National Extension Committee, and the National Higher Education Committee a statement and ranking of urgent priorities. The Regional Councils of the Joint Council presented regional views of significant priorities.

In May 1985, the Joint Council identified five major priorities for FY 1987 science and education programs. The Joint Council recognizes the importance of strong base programs in research, extension, and teaching and urges the continuance of support for these programs. Those priorities selected for special emphasis are particularly appropriate because of specific problems now facing agriculture and/or because of opportunities for important advances in these areas.

Recommended National Priorities

1. Increase Agricultural Profitability Through Management

Profitability has always been an important component of U.S. agricultural and forestry enterprises. To help the producers of food and fiber cope with the current difficult economic climate, the science and education system needs to develop multidisciplinary research and education programs focused on increasing farm and forest profitability. Attention should be directed to optimizing profits through better integration of production, management, and marketing strategies, including new uses for farm products, and to developing realistic family and business goals. Agricultural producers who face critical operating decisions need help in evaluating available alternatives. Producers also need assistance in developing management systems, including control and management of plant and animal pests and diseases, that will use human resources efficiently and produce maximum profit. Low-cost, efficient production systems will help U.S. agriculture remain competitive in world markets.

2. Improve Water Quality and Management

Protecting water resources and using them efficiently continue to be important concerns for agriculture and forestry. Natural sources of water are being threatened by toxic chemicals and atmospheric pollutants. In the arid West there is a need to utilize water supplies more efficiently through the application of feasible watershed management practices. Improved irrigation efficiencies can reduce both energy requirements and the importation of waterborne salt. Attention should be directed to assessing the impact of soil, water, and atmospheric pollutants on livestock and crops and to improving the

understanding by public officials and citizens about the nature of water resources. There is a need for increased understanding of relationships between crop production systems and the quality of ground and surface waters.

3. Expand Biotechnology Efforts on Plants, Animals, and Microbes
Through biotechnology, plants, animals, and microbes can be improved or modified to enhance their benefits to society. Recent innovations in genetic engineering techniques hold great promise for revolutionizing agriculture, forestry, microbiology, biology, and medicine. Molecular geneticists and conventional plant breeders are highly dependent upon a resource of genetic diversity, which must be assembled, maintained, and made readily accessible through an efficient system to develop the unique, productive organisms necessary for a stable, plentiful, and high-quality supply of food, feed, fiber, and forest products, and for the development of new uses for these products. Research should be expanded on transfer, expression, and regulation of individual genes and gene systems and on acquiring and conserving the maximum range of genetic diversity by appropriate sampling, collection, and preservation procedures.

4. Develop Necessary Scientific and Professional Human Capital
Today's American agriculture is a high-technology industry characterized by rapid and continual changes in methods of production, large investments in research, and an ongoing need for a highly qualified cadre of scientists and professionals to meet increasing demands for food and agricultural products. To achieve the goals necessary to meet projected needs, immediate action must be taken to increase the development of scientific and professional human capital. Steps which will enhance this activity are: expansion of pre- and post-doctoral fellowship programs, development of a national, computerized, higher education information system, implementing faculty revitalization programs, and strengthening curriculums.

5. Improve Human Nutrition and Understanding of Diet/Health Relationships.
Today's consumers are bombarded with nutrition advice from many sources. Some of this advice is unreliable, expensive, and not in keeping with the recommendations of nutrition scientists. Abundant production alone, without attention to quality factors, is not sufficient to assure consumer acceptance of products and adequate returns to farmers. Better linkage is needed between plant and animal production/processing as they relate to human nutrition requirements. More emphasis should be directed to determining human nutrient requirements under both normal and stressful conditions and their relation to long-term health factors. Improved technology to prevent, detect, and remove natural and environmental toxins and pathogens from food products is also needed. Consumers must be educated about problems faced by agricultural producers, and producers must be informed about desires of consumers for food products that enhance nutritional well-being.

Other Topics Considered

The Joint Council also discussed several other important priorities. They included: sustaining soil productivity; improving forest and range productivity; encouraging energy conservation; enhancing efficiency of agronomic and horticultural crop production; collecting, preserving, evaluating, and enhancing germplasm; reducing impacts of pests on plants; reducing impacts of atmospheric deposition and water pollutants on plants; augmenting livestock and poultry production efficiency; improving management of animal diseases and pests; and increasing aquatic food production.

Other priority items considered were: improving food quality and safety; improving family financial management; encouraging home horticulture; improving agricultural policy analysis; improving economic information on U.S. agricultural trade; expanding domestic and international markets for agriculture and forest products; expanding use of electronic communications/computer systems; increasing public education on agriculture; and developing volunteer leadership.

Narratives describing these additional prionties can be found in Appendix 2, pages 23 to 40.

Resources Needed

The active pursuit of priorities identified by the Joint Council will require both redirection of current programs and new funding. The Joint Council feels strongly that additional federal support is well justified. The opportunity to develop new human resources, new knowledge, and agricultural technology has never been greater. The need to transfer this new knowledge and technology to producers and consumers is equally great. As needs and priorities change, the agricultural science and education system has demonstrated that it can redirect programs. The potential for redirecting programs is not without limits, however, because the system must maintain a broad program base to continually update current technologies, respond to unforeseen emergencies, and educate future managers and scientists.

I. Introduction

Research and education are future-oriented activities—the research of today is developing the technology of tomorrow. Therefore, research and education policies and priorities must be based not on the emotions of the moment, but rather on the perceptions of future needs.

The time horizon for this report is the remainder of the century. During this period, adequate production would not be a problem if the demands for food and fiber were limited to the U.S. market. But our agricultural and forest product markets are global and increasingly interdependent.

The past three decades of global economic development have provided a major stimulus to U.S. agriculture. Production expanded by nearly 70 percent and the United States became a dominant supplier of grains and oilseeds in world trade. The growth in demand for U.S. grains, oilseeds, and cotton for the remainder of this century is likely to depend primarily on expansion of foreign demands. Growth in demand for meat and milk probably will depend largely on developments in domestic markets. These trends imply that U.S. agriculture will be increasingly export-dependent and increasingly cash-crop dependent.

This growing dependency on exports and cash crops has important implications for the selection of priorities in the agricultural sciences. On the production side, U.S. producers face increasing competition in the marketplace from producers in other countries. More efficient production technologies and improved management systems are required to keep U.S. production costs competitive in world markets.

Agricultural markets, always subject to the uncertainty of weather and government policy changes, are growing increasingly complex. This situation requires the development of specialized policies and agreements. In addition, improved transportation and storage technologies will be needed to maintain commodity quality and meet various foreign import regulations.

The growing dependency on cash crops means greater pressure on soil and water resources. Improved crop yields will tend to lessen the use of marginal lands for cash crops. Research in soil productivity will improve management of soil nutrients and provide more effective and affordable soil erosion control technologies. Improved water management techniques will increase the efficiency of use of limited groundwater supplies.

Finally, the outlook for the remainder of the century is for modest but steady improvements in the living standards of Americans. Rising living standards and educational levels will strengthen the consumer trends of the recent past. People will continue to be concerned about food quality, nutrition, and food safety. The proportion of meals eaten away from home and the demand for convenience foods can be expected to continue to increase. Concern about environmental issues is also likely to remain strong.

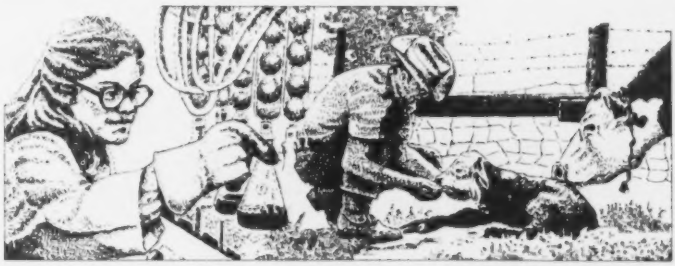
We can, therefore, look forward to the year 2000 with both concern and hope. Concern, because many food, fiber, and forest production, processing, and marketing problems lie ahead. Hope, because our research, extension, and higher education system has the capacity—if properly supported—to supply solutions to these problems.

This report discusses the most important issues and priorities for United States agricultural research, extension, and higher education for fiscal year 1987. In addition, it suggests the natural, human, and financial resources required to address these priorities. The Joint Council on Food and Agricultural Sciences, which was designated by Congress to prepare this report, includes members from: land-grant and other universities, representing research, extension, and higher education; foundations; producers; consumers; and USDA and other federal agencies.

The FY 1987 Priorities Report includes:

- A description of five critical national food and agriculture priorities identified by the Joint Council on Food and Agricultural Sciences as those on which the science and education system should focus its attention.
- A statement indicating the level of both federal and non-federal financial support of science and education in FY 1984 and an indication of needs in FY 1987.
- Descriptions of a number of additional important areas of emphasis for science and education. Although these areas were not included in the highest category of priorities, the Joint Council considers them to be of real significance to food and agriculture progress.
- A listing of priorities submitted to the Joint Council by National Committees, Regional Councils, and regional functional committees.

II. Selecting the National Priorities



To develop this FY 1987 Priorities Report, the Joint Council requested and received from the National Agricultural Research Committee, the National Extension Committee, and the National Higher Education Committee a statement and ranking of urgent priorities. The Regional Councils of the Joint Council presented regional views of significant priorities.

In addressing the science and education priorities for FY 1987, the National Committees and Regional Councils gave careful consideration to the current status of the food and agricultural system and to the problems and concerns of agriculture. Each Committee and Council ranked the priorities judged to be of greatest importance and submitted them to the Joint Council for consideration.

Priorities of the Research, Extension, and Higher Education Committees of the Joint Council[1]

National Agricultural Research Committee

The National Agricultural Research Committee (NARC) submitted 21 priorities for consideration by the Joint Council. These priorities came from priority rankings independently developed by the four regional agricultural research committees and submitted to the NARC.

The NARC pointed out that the U.S. public agricultural and forestry research system, representing a coalition of more than 100 units, is committed to serving high-priority national, regional, and state needs. The research system is highly adaptable and can mobilize and redirect resources to support new research agendas when needed.

Collectively, the agricultural and forestry base programs of each research agency constitute the foundation of the national system. It is crucial to the welfare of agriculture that state and federal funding give high priority to ensuring that those base programs remain broad, diverse, and dynamic, and that they are continually updated. From those base programs flow the knowledge and technology needed to meet most new challenges.

[1]A complete list of the priorities of the three National Committees of the Joint Council is in Appendix 1, Table 1.

National Extension Committee

The National Extension Committee (NEC) submitted 26 priorities to the Joint Council. The first 11 were given especially high ratings. The NEC priority rankings were developed by considering inputs from the State Extension Directors/Administrators, the National Extension Advisory Council (NEAC), and the federal Extension staff in response to a list of 29 topics submitted to them.

Regions generally agreed on priority rankings, but variation is apparent among several potential priorities. These include Integrated Reproduction Management, ranked higher in the Southern and Western Regions; Local Government, ranked higher in the North Central Region; Forest Resource Management, ranked relatively higher in the Southern and Western Regions; and Grazing Land Management, ranked relatively higher in the Western Region. Human Resource Development and Small and Home-Based Business are relatively more important among the 1890 institutions.

National Higher Education Committee

The National Higher Education Committee (NHEC) identified five priorities for emphasis in FY 1987. The NHEC emphasized the importance of attracting the brightest minds from the diminishing pool of students into the food and agricultural sciences and of providing the Nation with a continuing pool of well-educated agricultural scientists and professionals. Also emphasized was the importance of continued faculty renewal programs to maintain extant faculty on the cutting-edge of modern science. The development of necessary scientific and professional human capital must be a primal concern of the U.S. agricultural complex. Technology does not advance without professionals. Research is neither performed nor extended to industry without scientists. Steps must be taken now to deal with the increasing shortage of highly trained food and agriculture professionals and scientists. If action is delayed, the problem will intensify and have a detrimental impact on the entire food and agricultural system.

Priorities of Regional Councils and Committees[2]

The four U.S. geographic regions have different and distinct agendas dictated by environmental, social, and economic factors. Priorities were developed by the Regional Councils and Committees and by high-level agricultural decisionmakers within regions.

Northeast Region

Continuing changes in the Northeast agriculture, food, and forestry industries are affecting the educational and scientific institutions that service and support them. Some crop,

[2]Priorities of Regional Councils are shown in Appendix 1, Table 2. Regional research, extension, and teaching priorities are listed in Appendix 1, Tables 3, 4, and 5 respectively.

livestock, and forest production has shifted from the Northeast to other regions. The Northeast Regional Council submitted 10 priorities to the Joint Council, headed by basic research and scientific expertise development. Profitability in agriculture and farm financial and business management were the top two priorities of the Northeast Region Extension Directors.

North Central Region

More than 40 percent of the Nation's farm cash receipts are generated in this region. The region is an important producer of red meat, dairy products, food and feed grains, and oilseed crops. Major issues affecting this region are decline in farm profitability, soil erosion, competition for land use and resources, and export and commodity prices. The North Central Extension Directors placed farm financial and business management as their top priority, followed by profitability in agriculture. The North Central Agricultural Research Committee ranked biotechnology as the highest priority, followed by agricultural profitability.

Southern Region

Southern producers, like those in other U.S. regions, are faced with markedly lower profits. Soil erosion is a problem, and there is an urgent need to increase efficiency by focusing on plant and animal production systems. The Southern Regional Council submitted 13 priorities. The first was improved water management and water use efficiency; and second was improved animal health and reproduction. Extension Directors in the Southern Region gave profitability in agriculture and farm financial and business management their first and second rankings. The Southern Regional Research Committee placed the greatest emphasis on biotechnology, followed by soil and water management.

Western Region

The states in the Western Region have very diverse climates, topography, and agricultural commodity production. Water is a key to the West's economy. The Western Regional Council submitted 11 priorities for consideration by the Joint Council. Improving the use and conservation of water was the top priority of this Council, followed by product and market development. The Western Directors of Extension ranked agricultural profitability as their most urgent priority, followed by farm financial and business management.

Selecting the Top Priorities

After the Joint Council received the priority lists, the staff combined items covering similar areas. The consolidated list was first ranked in order of priority by Joint Council members individually. Subsequently, the Council met to discuss the proposals and select the five highest priorities for FY 1987.

III. Recommended National Priorities

Technologies that farmers need in order to remain competitive are costly and complex. Those who lack the capital and expertise to adopt a new technology early enough to maintain a competitive edge may find themselves in serious financial straits. The U.S. food and agriculture science and education system, which has been envied throughout the world, must face the challenges of the current economic climate. It must expand and refine past successes to help agricultural producers achieve more economical production. At the same time, the technology base for improving agricultural production efficiency must be increased.

Recognizing these factors, the Joint Council selected five priorities for FY 1987.

1. Increase Agricultural Profitability Through Management

2. Improve Water Quality and Management

3. Expand Biotechnology Efforts on Plants, Animals, and Microbes

4. Develop Necessary Scientific and Professional Human Capital

5. Improve Human Nutrition and Understanding of Diet/Health Relationships

A brief discussion of the importance of each of these priorities and the roles of research, extension, and higher education in contributing to solutions of problems is presented below.

Increase Agricultural Profitability Through Management

Agricultural profitability, always of importance to our Nation's food and fiber producers, is of particular concern in today's economic climate.

To help food and fiber producers cope with problems of depressed profit levels, the science and education system needs to develop and deliver research and education programs focused on increasing farm and forest profits. These programs require a multidisciplinary systems approach aimed at optimizing profit through better integration of

management, production, and marketing strategies. The **goal is maximum profit**, which does not necessarily imply maximum production. Emphasis must be on overcoming the current short-run financial crises and maintaining the long-run viability of agriculture.

The current situation developed as producers responded to growing exports, rising prices, accelerating inflation, and low real interest rates during the 1970's by **borrowing heavily to invest** in new labor-saving machinery and facilities, new production technologies, more land, real estate improvements, and increased use of fertilizer and chemicals. With falling exports, lower prices, higher interest rates, and lower incomes during the 1980's, the **increased debt burden has increased costs** and greatly limited management flexibility.

The critical decisions facing farmers and ranchers today are those dealing with farm management, operating efficiency of the total production system, financial planning, debt management, risk appraisal, family financial management, and economic survival. **Producers need help** in appraising their available resources, evaluating alternative opportunities and enterprises, and developing production systems that are viable, realistic, and economically feasible. The impact of farm finances on personal and family finances and of family goals on business goals needs to be understood and resolved.

Improved production and protection systems are needed on a continuing basis to improve efficiency and profitability for agronomic and horticultural crops, livestock and poultry, rangeland and forests. More effective methods for control and management of plant and animal diseases, insects, weeds, parasites, nematodes, and other pests and health hazards must be developed that are effective, economically sound, and environmentally acceptable.

The productive capacity of U.S. agriculture and forestry exceeds current domestic and foreign demand, with grain carryover continuing at burdensome levels. The weak demand for agricultural and forest products, especially for export, has had a depressing effect on commodity prices. A key to future profitability is **continued expansion of domestic markets including new uses for farm products, and recovery of the declining export market.** Continued research is needed to assure the improving productivity necessary to maintain the long-term viability of the agricultural sector by providing reasonably priced food, fiber, and forest products for the domestic market and competitiveness in foreign markets.

To restore more profitability in the food and agriculture system, more effective research, extension, and teaching are needed to:

- Develop total production systems to help producers optimize farm profits through better integration of production, management, and marketing strategies.
- Help producers analyze problems on an enterprise and commodity basis to identify profitable and unprofitable enterprises and determine the most economically viable production systems.

- Help producers understand the relationships among production decisions, financial management, risk management, and marketing alternatives and their impact on profitability.

- Encourage producers to adopt improved production practices aimed at cutting the cost of inputs and reducing losses while increasing product quality and improving net incomes.

- Expand the market for agricultural and forest products by increasing domestic utilization and consumption and by improving the ability of U.S. agriculture and forestry to compete in international trade.

- Help farmers, ranchers, and other rural land owners identify personal, family, and business goals and understand the financial impact of their decisions.

Improve Water Quality and Management

Protection and efficient use of water resources continues to be an important concern for agriculture and forestry. Natural sources of water are being threatened by toxic chemicals and atmospheric pollutants. Analytical capabilities to detect pollutants have greatly outstripped research on the effects of ingestion of minute concentrations of toxic chemicals. Thousands of disposal points for industrial and other toxic wastes are located in rural areas. These disposal sites pose a potential but unknown long-term threat to rural residents, livestock, plants, wildlife, and waterways.

Thirty-four states have identified agricultural nonpoint source pollution as a major cause of the failure to achieve state water quality goals. Twenty-nine states have identified nonpoint source pollution of groundwater as a major concern and have cited agricultural pesticides and septic tank seepage as primary causes. Much of the potential for pollution can be reduced through changes in soil-tillage practices.

In the arid areas of the Western States, there is a need to increase available water supplies through the application of improved watershed management practices on forest and rangeland. Improved management practices are also required to prevent salinity damage to highly productive crop-producing areas. Improved irrigation efficiencies can reduce both energy requirements and the importation of waterborne salt. A recently increased concern is the safe and economical disposition of drainage waters, some of which are contaminated with toxic metals such as selenium.

Improved research and teaching programs are needed to:

- Assess the impact of water and atmospheric pollutants on livestock, crops, and forest and aquatic ecosystems.

- Formulate improved management systems that optimize the use of chemicals, minimize erosion, and reduce the movement of pollutants to surface and ground water.

- Develop economical practices to increase water yields from forests and rangelands.
- Increase understanding of relationships between crop production systems and the quality of ground and surface waters.
- Improve soil and water management systems to reduce the impact of salinity in arid areas and to improve irrigation efficiencies.
- Design systems for the safe and economical disposal of contaminated irrigation waters.

Extension programs are needed to:

- Develop and implement coordinated interdisciplinary educational programs about the nature of our water resources; the importance of "pure" drinking water to human health and nutrition; the significance of water quality test data; the proper use, handling, and disposal of agricultural chemicals; the impact of various land uses; and the options for reducing pollution and keeping water safer for human use.

Expand Biotechnology Efforts on Plants, Animals, and Microbes

Biotechnology refers to the high-technology tools and techniques used in today's biological sciences. Through biotechnology, plants, animals, and microbes can be improved or modified to enhance their benefits to society. **Recent innovations in biotechnology and genetic engineering techniques** will likely revolutionize medicine, biology, microbiology, forestry, and agriculture. The techniques of plant cell and protoplast culture; plant regeneration; somatic hybridization; embryo transfer; and recombinant DNA approaches such as the identification, characterization, splicing, replication, regulation, and transfer of genes can be focused for improving plant, animal, and microbial species.

Studies of the structure and organization of genomes will require a major commitment to **developing germplasm collections.** The characterization of germplasm will lead to efforts to enhance the genetic makeup of organisms and to tailor production of specialty chemicals. Many of the recent biotechnological innovations are also applicable in the animal industries. Recombinant DNA and monoclonal antibody techniques can help characterize bacterial and viral antibody-antigen interactions and improve immunodiagnosis. In addition, they can enhance production of antigens and synthetic peptides as animal vaccines.

A diversity of improved genetic populations of plants, animals, and microbes will result in improved yield, quality, nutrient content, resistance to pests, response to adverse environmental stresses, harvest ratios, handling and storage, and compatibility with new production methods. Significant progress in this area will require development of the potential to **manipulate genomes rapidly and efficiently.**

Molecular geneticists and conventional plant breeders are highly dependent upon a resource of genetic diversity, which must be assembled, maintained, and made readily

accessible through an efficient system such as the National Plant Germplasm System (NPGS). The NPGS, a network of public and private workers and facilities, functions as the steward for the U.S. collection of plant germplasm.

Basic research studies will provide new knowledge and improve the fundamental understanding of cellular genetics and biology. These will serve as a base for further advances in biotechnology, assure continued growth in related sciences, and meet important agricultural and forestry needs. Areas of concern include: modification of the metabolite partitioning process, movement of nutrients into biological systems, development of specific hormonal entities, culture and regeneration of cells, development of microbes for processing of nutrient- and mineral-rich foods and feeds, and the subsequent development for farm products. Agricultural colleges and universities must consider making changes in curriculums to provide the necessary expertise.

The Division of Agriculture Committee on Biotechnology of the National Association of State Universities and Land Grant Colleges made an intensive study on "Emerging Biotechnologies in Agriculture". This publication emphasizes the importance of assessing **the potential biological and environmental impacts of releases of organisms containing recombinant DNA for agricultural uses.** it also focuses on the need to assign priorities in the biotechnology field.

Present research needs exist primarily in four areas:

- Structure, function, and organization of plant, animal, and microbial genomes.
- Transfer, expression, and regulation of individual genes and gene systems.
- Genetic control and molecular modification of growth, development, and resistance to physical and biological stresses.
- Preservation of the maximum range of genetic diversity.

Develop Necessary Scientific and Professional Human Capital

Modern agriculture is a high-technology industry characterized by rapid and continual changes in methods of production, large investments in research and technology transfer, and an ongoing need for a highly qualified cadre of food and agriculture scientists and professionals.

Historically, skilled and motivated high school students from agricultural backgrounds enrolled in "state of the art" agricultural colleges. After graduation, they entered agricultural industry or enrolled in graduate programs. Ultimately, these students became the scientists and leaders of the research and education system which undergirds our technological agricultural enterprise. The stability of this human capital base has deteriorated dramatically over the last decade. Between 1977 and 1983, baccalaureate

enrollments in agriculture at land-grant universities declined approximately 30 percent. During this same period, graduate enrollments diminished by 5 percent. Projections through the mid-1990's suggest a continuation of these trends. To some extent the decline may be attributed to demographic realities. However, between 1977 and 1982, total U.S. college enrollments were continuing to increase while agriculture enrollments were declining. Total U.S. college enrollments did not decrease until 1983. Hence the diminishing pool of college age youth cannot be the sole reason for declining enrollments in agriculture. Rather, we must recognize that the public's unidimensional "production" image of agriculture, combined with increasing competition from other disciplines, is contributing to the **reluctance of students to pursue degrees in the food and agricultural science disciplines.**

Agricultural expertise is vital to the security and well-being of this country. Our position as the lead Nation in agriculture requires an adequate scientific and professional human capital base. Several **national initiatives must be launched** jointly by the federal-state partnership, working cooperatively with the private sector, **to strengthen the food and agricultural sciences higher education system** as it competes with other disciplines, such as engineering and computer science, in the academic marketplace for outstanding students.

Competitive Graduate Fellowships and Research Apprenticeships

- Initiatives must be undertaken to attract and support outstanding science-oriented students. Specifically, the pre- and post-doctoral fellowship programs and the research apprenticeship program for high school students must be expanded and targeted to those areas with the most critical shortages of expertise.

National Information System for Higher Education Strategic Planning

- A comprehensive, computerized national information system must be further developed to provide baseline data for policy and program development, resource allocation, and program evaluation. This information system should include statistics such as enrollments, degrees conferred, employment demand for graduates, student financial aid, and faculty.

Strengthening of Institutional Capacities

- University faculties must be revitalized to assure continued program relevance. Innovative faculty developmental opportunities such as short-term sabbaticals and industry-government-academia exchange programs are needed to restore "cutting edge" science and technology to the agricultural classroom.

- "State-of-the-art" scientific equipment must be provided for instructional purposes to enhance higher education programs in the food and agricultural sciences.

- Curriculums must be strengthened if the system is to produce graduates at the forefront of knowledge and technology. Academia, government, and industry must cooperatively identify, prioritize, and promote needed curriculum improvements. Revision efforts must address not only the rapid expansion of knowledge but also the provision of experiences which will expand students' communications skills, decisionmaking competencies, agricultural ethics, and public policy analytical skills, as well as their ability to apply their specialized knowledge and skills in both the domestic and international arenas.

Improve Human Nutrition and Understanding of Diet/Health Relationships

Americans have access to more high-quality, moderately priced, safe and nutritious food products than any other people in the world. For many years we have taken for granted the availability of a plentiful supply of palatable, wholesome food. **Abundant production** alone, without attention to quality factors, **is not sufficient to assure consumer acceptance** of products and adequate returns to farmers. Farm products must be attractively presented to consumers with wholesomeness assured, quality maintained, and in accordance with market demand. Research and education efforts to improve quality and safety provide important linkages between production of high-grade agricultural products on one hand and consumption and human nutrition on the other.

In recent years, **public interest in nutrition, diet, and health issues** has been overwhelming. Today's consumers are bombarded with nutrition recommendations from many sources. Some of the recommendations are unreliable, expensive, and not based on well-documented nutritional facts. If this situation is not corrected, misinformation and confusion will continue to inundate the public. Nutrition education for consumers based on reliable research could have major implications for agricultural profitability and stability.

Quality assurance and hazard analyses are vital functions for control and protection by the food industry in the production, processing, packaging, storage, and distribution of agricultural products. Improved quality assurance makes sure that quality standards are met, contamination and deterioration are reduced, and shelf-life is extended to prevent product, nutritional, and economic losses. Good manufacturing practices and frequent safety inspections are necessary to ensure wholesome food.

Research has provided information addressing a number of perplexing questions. However, the metabolic relationship between nutrient intake and physiological response is exceedingly complex. Inadequate nutrition and improper dietary practices are contributing factors in various diseases and infant disabilities or mortality. Our knowledge of the relationships between nutrient quality and human genetic potential is scant, and our ability to alter naturally occurring food nutrients via biotechnology has barely scratched the surface.

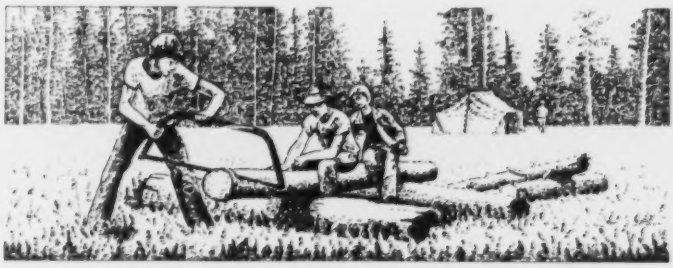
Research areas which need to be emphasized include:

- Determination of human nutrient requirements under both normal and stressful conditions and their relation to long-term health factors.
- Determination of the bioavailability of nutrients in foods.
- Investigation of the determinants of good dietary practices and educational strategies for promoting good nutrition.
- Assessing the effects of production and postharvest technology on quality, acceptability, and food safety.

Extension emphases are needed to:

- Formulate strategies for educating consumers about the realities of agricultural production and marketing as well as making producers aware of consumers' desires for products that enhance nutritional well-being.
- Establish communication among clientele, producers, processors, extension educators, researchers, and policymakers so that unified messages about nutrition and health can be evolved and supported.
- Educate the consumer on proper food storage and handling to maximize nutrient retention and food safety.

IV. Financial Support Needed for Priority Programs



Financial support for public research, extension, and higher education in the food and agricultural sciences is derived from many sources; however, state, local, and federal appropriations provide the major source of the sustained funding necessary for long-term commitments. Such long-term commitments are necessary for both technology development and human resource development. Priority programs are addressed through real increases in appropriations, by redirection of ongoing programs, and by contracts and grants.

While state-managed science and education programs respond principally to needs expressed at the regional, state, and local levels, they also address national and international issues. On the other hand, although federally-managed science and education progams are directed primarily at national and regional issues, the findings often can be utilized effectively at state and local levels, where producers and consumers make their individual decisions. Judgments about whether programs can be most effectively and efficiently performed by the public or the private sector are based on several criteria, among which are the intended recipients of the benefits and the potential market size.

The U.S. Department of Agriculture supported research and education programs in the food and agricultural sciences in the amount of $1.1 billion in fiscal year 1984. Expenditures were divided among several USDA agencies: Agricultural Research Service ($455.8 million), Economic Research Service ($43.7 million), Forest Service ($108.7 million), and Office of International Cooperation and Development (OICD) ($7.9 million). State agricultural experiment stations and state cooperative extension services received formula distributions from Cooperative State Research Service ($208.3 million) and Extension Service ($289.9 million), respectively. Higher Education Programs had a graduate fellowship program ($5.0 million) and supported resident instruction programs through the Morrill-Nelson Act ($2.8 million) in 1984.

Nonfederal support (mostly state and local government appropriations) for food and agricultural research and extension programs was $1.4 billion in fiscal year 1984. State funding for instruction by land-grant and other colleges and universities exceeded $1 billion.

Subject Matter	Research ($Mil.)		Extension ($Mil.)		Higher Education ($Mil.)	
	USDA	Nonfederal	USDA	Nonfederal	USDA	Nonfederal
	1984	1984	1984	1984	1984	1984
Natural Resources	207.8	129.7	12.2	34.9	0.5	
Crop Production and Protection	278.6	316.3	60.9	150.1	1.8	
Animal Production and Protection	148.0	237.6	35.6	87.8	1.2	
Processing, Marketing, and Distribution	126.4	70.4	36.8	40.3	2.1	
People and Communities	57.0	30.0	144.4	298.6	1.6	
Agricultural and Resource Policy	10.9	29.2	--	--	0.6	
Unclassified	0.1	0.2				
Totals	**828.8**	**813.4**	**289.9**	**611.7**	**7.8**	**>1000.0**

Other federal agencies also support programs related to food and agricultural research, extension, and higher education. The most recent estimate of this support, made in 1982, was $581.2 million.

The Joint Council feels strongly that additional federal support is well justified. The opportunity to develop new human resources, knowledge, and agricultural technology has never been greater. The need to transfer this new knowledge and technology to producers and consumers is equally great.

Appendices

Appendix 1

Priorities Recommended by the National Research, Extension, and Higher Education Committees, Regional Councils and Committees

Table 1. Priorities for FY 1987 in Agricultural Research, Extension, and Higher Education Submitted by National Committees[1]

National Agricultural Research Committee	National Higher Education Committee	National Extension Committee
1. Water quality and management	1. Expand the pre- and post-doctoral fellowships programs and research apprenticeship programs to attract outstanding students into food and agricultural specializations characterized by current/projected shortages of expertise.	1. Profitability in agriculture
2. Strengthen market penetration for current and new agricultural and forest products	2. Develop a national computerized higher education information system that provides essential data for strengthening policies and programs directed toward enhancing our food and agricultural higher education system.	2. Farm financial and business management
3. Sustaining soil productivity	3. Update and revitalize college and university faculty in the food and agricultural sciences	3. Water quality and management
4. Livestock and poultry profitability and product quality	4. Initiate an institutional strengthening grants program targeted toward improving higher education in the food and agricultural sciences.	4. Family financial management
5. Human nutrition	5. Promote needed curriculum revisions aimed at producing graduates at the forefront of knowledge and technology.	5. Human nutrition and health
6. Increase profitability of agronomic and horticultural crops		6. Marketing agricultural and forest commodities
7. Forest and range management		7. Youth development/lifelong education
8. Management of animal diseases and pests		8. Scientific expertise and human resource development
9. Integrated management systems		9. Crop management systems
10. Germplasm collection, preservation, evaluation, and enhancement		10. Livestock and poultry management systems
11. Competitiveness of U.S. agriculture and forest products in world markets		11. Soil conservation and productivity
12. Food quality and safety		12. Forest resource management and wood utilization
13. Management of plant pests		13. Family strength and well-being
14. Agricultural policy analysis under alternative monetary, fiscal, and trade policies		14. International development and trade
15. Human resource development		15. Volunteer development
16. Effects of air and water pollutants on plants		16. Integrated pest management
17. State-of-the-art equipment and facilities		17. Electronic communication/computers
18. Conservation and development of energy		18. Aquatic food production
19. Rural family and community resource management and economic development		19. Public education in agriculture
20. Aquatic food production		20. Home horticulture
21. International science interdependence		21. Economic and small and home-based business development
		22. Wildlife and fish management
		23. Local government and organization
		24. Natural resource and policy education
		25. Grazing land management
		26. Agricultural weather

[1]Priorities are listed in rank order.

57-279 O - 87 - 32

Table 2. Priorities for FY 1987 in Agricultural Research, Extension, and Higher Education Submitted by Regional Councils[1,2]

Northeast Regional Council	Western Regional Council	Southern Regional Council
1. Basic research	1. Improve the use and conservation of water	1. Improve water management and water use efficiency
2. Scientific expertise development	2. Product and market development	2. Improved animal health and reproduction
3. Human nutrition	3. Improve agricultural profitability through farm management	3. Develop recombinant DNA and monoclonal antibody techniques for characterization of bacterial and viral epitopes and to aid immunodiagnosis and production of antigens and synthetic peptides as vaccines
4. Sustaining soil productivity	4. Recruitment of high-quality students	4. Plant germplasm collection, maintenance, enchancement, and evaluation
5. Water quality and management	5. Improve quality of higher education	5. International supply, demand and price relations for major U.S. export commodities
6. Food processing and marketing efficiencies	6. Improve production systems and resource management	6. Development of improved cropping and management systems for important agri-ecosystems
7. Family resource management	7. Identify interrelationships among diet, human nutrition, and health	7. Development of animal production and management systems for improving acceptability and market quality
8. Alternate production systems	8. Expand research and education in biotechnology	8. Reduced soil erosion from wind and water
9. Improved public education delivery systems	9. Enhance family well-being through improved resource management	9. Postharvest handling, storage, and processing for maintenance and improvement of crop quality and utilization
10. Forest productivity and best management practices	10. Improve technology for the use and conservation of energy	10. Development of effective pest management systems
	11. Enhance human potential through youth and volunteer development	11. Increase the number of trained personnel to support the Nation's agricultural industry
		12. Development and utilization of engineering systems for efficient crop production
		13. Innovative, safe, and nutritious food products for modern society

[1]Priorities are listed in rank order.
[2]Priorities were not submitted by the North Central Regional Council.

Table 3. Ranking of Priorities by the Regional Agricultural Research Committees[1]

Northeastern	North Central	Southern
1. Basic research	1. Biotechnology of plants, animals, and microbes	1. Biotechnology for the improvement of crop and animal species
2. Human nutrition and food safety, quality, and acceptability	2. Enhancing long-term profitability of agriculture	2. Engineering systems for soil and water management for efficient crop production
3. Animal productivity	3. Integrated crop production systems	3. Pest management systems for crops
4. Soil, water, and energy resources	4. Basic research on the biology of agricultural plant and animal species and their pests	4. Animal reproduction
5. Forest productivity and development	5. Improve insect and disease occurrence and control models in plants	5. Germplasm development and enhancement
6. Plant productivity	6. Reduce impact of diseases in livestock and poultry production	6. Control of animal diseases
7. Economics of agriculture and forestry	7. Improve production systems for agronomic and horticultural crops	7. Improved cropping and management systems
8. People and communities	8. Short-term adjustments in production systems to improve economic efficiency, minimize risks, and increase net farm income	8. National and international supply and demand, price relations and marketing systems for agricultural products
Western	9. Improving livestock and poultry production systems	9. Animal production and management systems
1. Expand supplies, protect the quality, and improve the use and conservation of water	10. Expand markets for high-quality agricultural products	10. Biology, culture, and management of forests and timber-related crops
2. Biotechnology and genetic engineering	11. Improving human nutrition	11. Crop modeling for more efficient crop management systems
3. Increase productivity and efficiency of western food and fiber systems	12. Support of graduate programs to train future scientists	12. Postharvest handling, storage, and processing for maintenance and improvement of product quality
4. Improve the safety and nutritional quality of the Nation's food supply	13. Meeting growing needs for new high-tech research equipment and replacing obsolescent equipment	13. Improved acceptability and market quality of animal products
5. Improve knowledge and technologies for agricultural management and policy decisions	14. Resources to maintain current programs	14. Impact of air and water quality on crop production
6. Expand supplies and improve the use and conservation of energy	15. Enhance profitability of forests and forest products	15. Aquatic food production
		16. Agricultural, monetary, and foreign trade policy with emphasis on agribusiness

[1]Priorities are listed in rank order.

Table 4. Ranking of Priorities by Extension Directors[1]

Northeast	North Central
1. Profitability in agriculture	1. Farm financial and business management
2. Farm financial and business management	2. Profitability in agriculture
3. Human nutrition and health	3. Family financial and business management
4. Family financial management	4. Human nutrition and health
5. Marketing agriculture and forest commodities	5. Soil and water conservation and management
6. Youth development/ lifelong education	6. Youth development/ lifelong education
7. Integrated pest management	7. Family strength and well-being
8. Volunteer development	8. Volunteer development
9. Soil and water conservation and management	9. Economic development
10. Agricultural chemicals management	10. Electronic communications/computers
11. Crop management systems	11. Marketing agriculture and forest commodities
12. Electronic communications/computers	12. Crop management systems

[1]Priorities are listed in rank order.

Southern	Western
1. Profitability in agriculture	1. Profitability in agriculture
2. Farm financial and business management	2. Farm financial and business management
3. Family financial management	3. Youth development/ lifelong education
4. Youth development/ lifelong education	4. Family financial management
5. Marketing agriculture and forest commodities	5. Human nutrition and health
6. Public education on agriculture	6. Volunteer development
7. Human nutrition and health	7. Soil and water conservation and management
8. Soil and water conservation and management	8. Marketing agriculture and forest commodities
9. Crop management systems	9. Family strength and well-being
10. Electronic communications/computers	10. Integrated pest management
11. Volunteer development	11. Crop management systems
12. Integrated pest management	12. Electronic communications/computers

Table 5. Higher Education Priorities[1] for FY 1987 Submitted by Regional Higher Education Committees[2]

Northeastern	Western
1. Strengthen efforts to recruit academically outstanding students into food and agricultural sciences higher education programs	1. Attract outstanding science-oriented students into college and university degree programs in the food and agricultural sciences
2. Develop a national computerized higher education information system	2. Develop a national computerized information system that will provide essential data for analyzing and strengthening our Nation's food and agricultural higher education system
3. Expand faculty development opportunities	3. Modernize instructional facilities and scientific equipment
4. Provide for state-of-the-art scientific instrumentation for instructional purposes	4. Revise university curriculums to produce graduates at the forefront of knowledge and technology
5. Revitalize university curriculums across the food and agricultural sciences	5. Revitalize college and university faculty in the food and agricultural sciences

[1]Priorities are listed in rank order.
[2]North Central and Southern Regions did not submit higher education priorities.

Appendix 2

Other Important Priorities

Nineteen additional priorities considered by the Joint Council, all of which are important to continued progress in the U.S. food and agricultural system, are described in this Appendix. Some of the information presented here has also been used in the narratives for the top five priorities. **The narratives presented in the subsequent pages are grouped according to subject-matter area and are not arranged by priority.**

Sustain Soil Productivity

Soil resources are a primary determinant of the productivity of our crop, range, and forest lands. Accelerated soil erosion by wind and water is an important national problem. In addition to long-term degradation of the soil resource base, erosion creates sediment which causes large and continuing offsite damages. The Conservation Foundation estimates that annual losses to recreation, fisheries, water facilities, and water users from agriculturally related sediment total $4 billion per year.

Productivity problems related to erosion include the loss of effective water-holding capacity and plant nutrients and organic matter as well as surface-soil attributes which enhance infiltration of water and seed-bed characteristics.

Both conservation tillage practices, which have been widely adopted because of strong economic incentives (lower labor, machinery, and energy requirements), and shelterbelts help reduce soil erosion from wind and water.

The success of conservation tillage practices provides an opportunity to promote the concept of soil conservation, fertility management, and input-conserving practices as parts of new and improved plant production systems. This situation presents a challenge for the coordinated efforts of basic and applied researchers, teachers, extension workers, and soil conservationists.

Research and teaching programs are needed to:

- Improve understanding of the relationship between erosion and soil productivity.
- Trace the movement and impact of sediment within fields, forests, and watercourses.
- Refine methods for estimating onfarm and offsite damages from erosion and sediment.
- Improve understanding of the relationship between soil nutrients and tillage practices, including studies of the ecology of soil microorganisms.
- Design complementary research activities to improve crop, range, and forest land management by developing new, lower-cost, resource-conserving plant production systems.

Extension programs are needed to:

- Cooperate with other government agencies and private organizations to motivate farmers and other land managers to increase the rate of adoption of new technologies that optimize the use and conservation of soil resources.
- Develop and disseminate information about the impact of wind and water erosion on agricultural land and on offsite facilities, recreation, and water users.
- Promote the concept of new plant production systems designed to accelerate the adoption of cost-effective, economically feasible soil conservation practices to reduce the impact of soil erosion on both producers and consumers and encourage the shift of marginal lands to conservation uses.

Improve Forest and Range Productivity

Most of the extensive acreages of forest and range resources (71 percent of the total U.S. land area) can be managed to produce more useful products through multiple use. These products include timber, pulpwood, forage, water supplies, wildlife habitat, fuels, minerals, and recreation opportunities.

Future timber and pulpwood availability will be influenced by the productivity of nonindustrial forest land, conversion of forested lands to other uses, and the increased use of wood for fuel. Fifty-eight percent of the Nation's productive forest land is held by 7.7 million priv of forested lands to other uses, and the increased use of wood for fuel. Fifty-eight percent of the Nation's productive forest land is held by 7.7 million private landowners. Current production of private forest lands is less than half the potential. Better management practices designed to increase production and lower costs can help to realize this potential in an increasingly competitive international market for wood products.

Improved management and emerging technology in silvicultural and protective practices—genetically improved trees, integrated pest management, reforestation, thinning, fertilization, and use of system analysis—have the potential to double or triple the production of major softwood species.

Rangelands are also being managed below their physical potential. The ecological status of grazing lands is improving; however, 38 percent is still in poor condition and 16 percent remains in very poor condition. Encroachment of weeds and bushes is a problem in 300 million acres. Soil erosion is a serious problem in many locations.

Research, extension, and teaching programs are needed to:

- Use basic biotechnology techniques for development of genetically improved, pest- and disease-resistant trees and range plants.

- Find and improve range grasses that will prosper in subregions with varying combinations of climate and soil characteristics.
- Develop low-cost practices for protection of forests from insect, disease, and fire losses.
- Improve harvesting and processing operations to increase product yields, lower costs, and lessen environmental damages.
- Develop improved low-cost management practices for range ecosystems to increase production and utilization of forage plants while protecting the soil resource.
- Increase landowner knowledge of more productive and profitable management practices and markets for wood products.
- Improve landowner returns from management of forest and range lands for hunting or other recreation uses.
- Improve public understanding of forest and range resources and multiple-use potentials in order to reduce user conflicts and improve long-term productivity.

Encourage Energy Conservation

The production, transportation, and processing sectors of U.S. agriculture account for 16.5 percent of all energy used in the United States. Imported fuels are the largest single category contributing to the current record-breaking trade deficit.

The stunning escalation of petroleum prices in the 1970's provided incentives both for consumer and industrial conservation and for research into improved, energy-efficient processes and alternative sources of energy. In agriculture, there has been a flurry of interest in alternative hydrocarbon fuels, biomass, and the development of more efficient equipment and cropping practices, such as reduced tillage and more efficient use of fertilizer.

Recent declines in the prices for petroleum and other fossil fuels stem in large measure from the spectacular successes in energy conservation in the United States and other industrial countries, and, to a lesser extent, the slowdown in global economic activity. The fall in prices has appeared to remove some of the immediate urgency to consider energy a leading problem. This attitude is short-sighted, however, because: (1) energy is a major input into agricultural production and deserves attention as a part of the general search for ways to reduce production costs, (2) the decline of nuclear energy and the increasingly serious environmental problems associated with coal can be expected to put upward pressure on prices for petroleum and natural gas, and (3) developable supplies of petroleum and natural gas are limited and world production may peak in the foreseeable future. U.S. petroleum production has already peaked.

Continuing research activity will be essential to facilitate long-term adjustments in agricultural energy use and production.

Research programs are needed to:

- Develop more energy-efficient systems consistent with overall efficient systems for producing, harvesting, processing, and transporting agricultural products.
- Continue development and evaluation of the feasibility of using agricultural resources to provide alternative energy sources.

Extension programs are needed to:

- Encourage the adoption of cost-lowering and energy-conserving technologies in the production, processing, packaging, and distribution of agricultural and forest products.

Enhance Efficiency of Agronomic and Horticultural Crop Production

The inability of some agronomic and horticultural crop production systems to provide commodities at competitive prices has created a crisis for many producers. This situation is exacerbated by instability of prices and exports, severe cash flow problems, relatively high interest rates, and stable or declining asset values. U.S. agriculture is at a critical junction, particularly since the outlook for the next 2 to 5 years is for continued instability of production capacity, plus a slower rate of growth in demand for crops.

An accurate identification of the needs of these producers is urgently needed. The resources required to address these needs must be assembled and programs must be initiated to solve the key problems that are deterrents to future crop production efficiency.

A multidisciplinary research, extension, and teaching approach is needed, on a commodity and farm basis, to develop total production systems designed to improve efficiency of agriculture.

Research is needed to:

- Explore ways to enhance the competitiveness of U.S. agriculture in the world market.
- Identify and improve marketing opportunities, with effective alternatives.
- Incorporate biotechnology approaches in conventional plant breeding to reduce input costs by developing improved varieties which will suffer fewer adverse effects from disease, insects, nematodes, temperature and water stress, and competition from weeds.

- Use genetic engineering to alter plant structures and shapes to improve harvesting and maturing processes and possibly reduce production costs and improve quality.

- Develop ways to modify existing cultural practices, such as crop rotations and tillage procedures, in order to enhance profitability.

Extension and teaching programs are needed to help present and potential producers, and their supporting industries, to:

- Analyze farm records to identify efficient and inefficient production practices, enterprises, and alternatives.

- Clarify the relationships between crop management decisions, risk management, and marketing alternatives and their impacts on crop production efficiency.

- Identify short- and long-term production trends and their implications.

- Adapt to changing demands, production practices, and farm policies.

- Explore opportunities for alternative crops and/or for diversification.

Collect, Preserve, Evaluate, and Enhance Germplasm

The expanding human population is destroying the plant genetic diversity that it must have to feed itself. Genetic diversity is the basis for selection of new germplasm and an essential tool in genetic improvement. Changing land-use patterns, brought on by man's need for living space and material goods, are destroying habitats of primitive crop varieties and their wild relatives, the principal sources of genetic diversity. Increases in production efficiency come from better pest resistance, improved reaction to adverse environmental stresses, increased yield and nutritional value, and development of the quality characteristics which are preferred in the marketplace. Diverse genetic material must be assembled, maintained, evaluated, and made available through a strong national plant germplasm system.

The National Plant Germplasm System (NPGS) provides the coordination necessary for collecting, preserving, evaluating, and enhancing needed germplasm. The NPGS directly affects the scientific community, agricultural producers, processors, and consumers. Crop hazards such as diseases and insects change over time in their ability to attack originally resistant varieties; production systems are altered by environmental and energy constraints; and consumer demands and needs for products with improved nutritional value change in response to improved dietary information and economic considerations. A large assortment of reserve genetic material is necessary in order to alter crops in response to these changes.

Every U.S. citizen is affected by adequate supplies of plant germplasm, because reasonably-priced high-quality food comes mainly from the more efficient varieties and

hybrids. Because of the "bred-in" protection against disease and insect pests, drought, cold, and other production hazards, the consumer is assured a stable food supply and less environmental pollution.

Research efforts must be intensified:

- To acquire unique plant germplasm, since plant species and varieties are becoming extinct at a rate unprecedented in man's history.
- To evaluate acquired germplasm to determine its potential value to crop breeders and other users.
- To enhance selected genes so the user community can benefit from the valuable germplasm identified.

Reduce Impacts of Pests on Plants

There is an increasing need to develop more effective methods for pest management, taking into consideration the effects on environmental quality as well as the economic impacts. Insects, plant diseases, weeds, nematodes, and vertebrates cause losses greater than 30 percent during the production, marketing, and storage of agricultural and forestry crops in the United States. Producers spend more than $10 billion each year in efforts to control these pests.

Integrated pest management has been extremely useful for pest control. Reduction of the adverse impacts of pests on plants is best attained with a systems approach based on a fundamental understanding of the pest-host relationship. This approach utilizes selective chemicals, biological control agents, resistant plant varieties, and sound cultural practices. The systems that emerge through this approach will be economically feasible and environmentally acceptable. Biotechnology will provide new options for improving the effectiveness of pest management while reducing costs.

Research is needed on:

- The biology and interactions of pests, their hosts, and natural enemies and on the unique characteristics of the metabolic pathways of pests.
- Pest population dynamics, genetic diversity, movement/dispersal, and behavior.
- Refined diagnostic, sampling, and forecasting techniques.
- The benefits and risks of using pest control chemicals which have critical agricultural and forestry uses.

Extension and teaching are needed to:

- Develop curriculum changes that provide in-depth knowledge and understanding of the basic biologies of crop plants to be protected and of pests to be controlled.

- Train pesticide applicators to enable them to use pesticide products safely and dispose of unused quantities in ways that have minimal detrimental effects on the environment.

- Train county extension agents in the principles and practice of integrated pest management techniques.

Reduce Impacts of Atmospheric Deposition and Water Pollutants on Plants

Air and water quality must be improved in order to reduce adverse impacts on crops, forests, ornamental plantings, and off-site water needs. Pollutants from agricultural chemicals, industrial emissions, and naturally occurring sources enter the atmosphere through volatilization, drift, and wind erosion. Materials from waste disposal sites leach into surface and groundwater systems and percolate into aquifers. These processes have caused a deterioration in the quality of our air and water resources and are threatening the economic health of agriculture and forestry in some areas of the United States.

The economic well-being of agricultural crop and forest production, particularly in the Western States, requires a continuing supply of large amounts of water at specific times. In some cases, water used for irrigation has become laden with salts and agricultural chemicals, creating serious crop phytotoxicity problems for subsequent users.

Since the 1940's, there has been increasing concern about the effects of air pollutants, particularly ozone and oxides of sulfur and nitrogen, on agricultural and forest resources. During the past 10 years, that concern has focused in part on the acidic precipitation, or acid rain, which is affecting crops, forests, soils, and surface waters.

Acid rain has become a polarized, emotional national issue. Before it can be resolved, it will be imperative to gain a better understanding of the total chemistry of the atmosphere. For example, acid precipitation must be considered along with gaseous and dry particulate pollutants.

State, federal, and industry scientists already are cooperating to determine effects of atmospheric deposition on crops, forests, soils, surface waters, and materials such as buildings, bridges, and monuments. A relatively small funding base supports crops effects research. Funding for forestry effects research has increased significantly because of unexplained declines in forest stands in the Southeast and Northeast. Pollutants have been implicated in these declines.

Research and extension programs are urgently needed on:

- Interactions of atmospheric deposition with other air pollutants, such as ozone and oxides of sulfur and nitrogen, that affect the growth of crop and forest species.

- Technology for monitoring total ambient atmospheric chemistry, integrating wet-deposition and dry-deposition concentration measurements over major agricultural and forestry regions.

- Alternative management systems and new cultural practices that have minimal adverse impacts on the water supply while maintaining water use efficiency.

- Impact which the leaching of basic ions from soils has on soil productivity and the quality of irrigation water and watersheds.

- Procedures for determining effects of long-term exposure to chronic pollutants.

Augment Efficiency of Livestock and Poultry Production

Many commercial livestock and poultry producers are in serious financial difficulty. The keys to future profitability and stability for these and other producers include: accurately identifying producer needs, assembling the resources required to address these needs, and orchestrating programs which effectively solve problems. The year round production and care of slaughter and dairy animals and poultry can benefit from further research and extension efforts on key components of animal production systems.

In spite of the importance of livestock products to the consumer and the importance of livestock enterprises to American agriculture, numerous problems limit further improvements in production efficiency of animal agriculture. Many of these problems can be solved only by the creation of new technology or by more widespread adoption of existing technology.

Reproductive inefficiency has consistently been identified as one of the most costly and production-limiting problems facing the animal industries. Although significant progress has been made in our understanding of the reproduction phenomenon, improvements in reproductive efficiency have been slow.

The forage-ruminant complex is one of the major food-production systems of this and many other countries. A highly efficient and economic system for the conversion of solar energy (via plants) to human food depends on improved management systems for forage production and utilization by ruminant livestock.

Additional research attention should be directed to:

- Cellular and molecular processes regulating protein synthesis and fat metabolism.

- The absorption, assimilation, and utilization of nutrients.

- Physiological and endocrinological factors associated with high reproductive efficiency.

- Genetic and physiological relationships among traits.

Education efforts should be expanded to:

- Encourage the use of a systems approach to improve reproduction, nutrition, housing, health, management, marketing, and financial practices while improving quality of products and increasing net income.

- Develop and make available models that forecast for specific livestock and poultry systems the results of various inputs in terms of yield, income, and capital requirements.

Improve Management of Animal Diseases and Pests

Diseases of food animals are important causes of reduced production efficiency. Livestock and poultry producers face major and unpredictable risks of substantial losses from diseases, parasites, and other health hazards. In the United States, 15 to 20 percent of food animals die before reaching market. Some exotic infections, such as African swine fever, viscerotropic, velogenic Newcastle disease, and foot-and-mouth disease are serious threats to the U.S. livestock industries. Most highly contagious epidemic diseases have been controlled. Production diseases, many of which present no recognizable clinical signs, are the most important contributors to reduced productivity. These losses, plus the inefficiencies caused and the treatment costs for animals that recover from illness, are equal to an estimated 25 percent of the annual cash income for livestock and poultry.

Market competition and modern production practices, including high costs for labor, investment, and facilities, have required that large numbers of animals be kept closely confined. Despite the many health advantages to this practice (health surveillance; protection from parasites, predators, and climatic extremes; and accessibility for better health care) the spread of certain diseases is enhanced by the proximity of animals in a group. Because of public concern, the use of some medicants available for controlling animal health hazards is threatened. New or altered technology must be developed to combat new diseases or to replace measures no longer permitted or no longer effective. The use of recombinant DNA technology to produce vaccines and other biological materials at reasonable cost is encouraging.

Increased research effort is needed to:

- Characterize interactions between stress and disease.

- Study nonchemical control of pests and disease vectors.

- Develop vaccines and diagnostic tests through immunogenetic and bioengineering techniques.

Additional extension emphases are necessary to:

- Acquaint producers with housing and management techniques necessary to reduce losses from pests and diseases.

Increase Aquatic Food Production

Aquatic food production, an old idea that has found a new emphasis, is an expanding enterprise with considerable economic potential. It affords opportunity to help keep prime lands and waters in production, meet increased demand for fish, reduce dependence on imported and wild fish products, increase rural employment and farm income, and increase availability of high-quality fish products.

An interdisciplinary research approach is needed to:

- Develop efficient and profitable production management systems.
- Improve food-product quality.
- Improve food-processing procedures.
- Enhance new food-product development.
- Alleviate transportation and marketing problems.

Extension efforts are needed to:

- Improve rapid transfer and adoption of research-based technology to solve major nutrition, health, pest, and financial problems.
- Improve financial and risk-management expertise of growers, processors, and marketers.
- Assist in orderly development of expanded marketing opportunities through electronic data base management.

Improve Food Quality and Safety

A complex but effective interaction of the private and public sectors in research, education, regulation, and management contributes to the quality and safety of our food supply. Research and education efforts to improve quality and safety provide important linkages between production of high-grade, wholesome agricultural products on one hand and consumption and human nutrition on the other. Constant vigilance and testing are required throughout the marketing channels to assure that quality is maintained and foods are safe.

The safety and quality of our food supply is so consistent that it is often taken for granted. But new problems keep emerging and there is still much basic knowledge and application needed to continue to improve food quality and safety. Continued research and education are needed about the chemical, physiological, and molecular processes and properties of agricultural products, developing and utilizing new processing and handling

technologies, quality evaluation procedures, reduction of nutrient losses, and determination of new quality and safety standards and procedures.

More emphasis is needed on:

- Developing improved technology to prevent, detect, and remove natural and environmental toxins and pathogens from food products.
- Devising more efficient and safe food processing and handling methods.
- Improving the nutritional quality and nutrient bioavailability of food products through production and processing approaches.
- Ascertaining the safety of new food products and processes.
- Developing new chemical, mechanical, or electronic methods for more objective evaluation of quality and acceptability.
- Assuring that food products contribute to nutritional well-being.

Improve Family Financial Management

American families are called on to make increasingly complex financial and resource management decisions. Family financial problems compound when net farm incomes go down and financial stress increases. Deregulation of financial and consumer services has not only expanded the choices but also increased the decisionmaking responsibilities and hazards of families. People need accurate information and improved skills to assure family economic stability in planning and implementing for both short- and long-range goals.

Family financial management focuses on the acquisition, allocation, and conservation of personal and family incomes and on the household's ability to plan and use resources to achieve financial goals and maintain a desired level of living. It includes decisions concerning employment, education, food purchases, energy conservation, housing choices, credit uses, retirement, and estate planning. To make informed decisions in these areas, families need to understand how their needs and goals change over time and how to interpret economic, financial, and market trends that influence their choices.

The goal of family financial management assistance is to provide accurate, timely, and useful information and to develop family financial skills that will:

- Improve understanding of the long-run consequences and interrelations of financial decisions made early in life.
- Help consumers understand and assess financial risks inherent in both new and established financial services and instruments.

- Help families enhance their income-earning capabilities by developing home-based businesses and by marketing the skills of family members.

- Improve capacity of families to manage food, housing, household, clothing, energy, and credit costs, thereby increasing family stability and security.

Encourage Home Horticulture

Gardening traditionally has been an integral part of most farm operations. Farm families grow fruits and vegetables primarily to improve their diet and nutrition, but gardening also can provide an income supplement, job opportunities for family members, recreation, and therapeutic benefits. Home canning and freezing of horticultural crops extend the enjoyment and nutritional benefits of home-produced fruits and vegetables throughout the year.

Urban areas have many vacant spaces that can become eyesores, encourage vandalism, contribute to unchecked weed growth, and create health hazards. At the same time, many people with low incomes and poor nutrition gravitate to the cities. The urban gardening program was developed to help those people with the greatest need produce vegetables to supplement their diets and incomes on land donated for this public use. In many cases, urban gardening is the first exposure of urban youth to the concept of where food comes from.

The migration of urban residents to the suburbs has produced a new generation of gardeners who are eager but unskilled. They have added an unprecedented increase to the Extension workload in suburban areas. New technology and new methods, such as master gardeners, horticulture hotlines, taped messages, and similar approaches provide assistance on a more cost-effective basis.

Home horticulture programs can:

- Improve diets and supplement incomes while providing recreation and job opportunities for family members.

- Transform blighted urban areas and encourage community pride by using those areas for food production and recreation.

- Encourage young and adult gardeners to appreciate natural resources, accept responsibility, develop personal satisfaction, and create pride in their neighborhood.

- Expand the core of volunteer master gardeners that will enable Extension to provide better service to clientele who are interested in growing gardens, lawns, and shrubs.

Improve Agricultural Policy Analysis

American agriculture has changed. Large commercial farms dominate U.S. farm production. The operators of the remaining smaller farms generally are not poor and do not depend solely on farm income. Many of the commercial farms can be competitive in world markets, but may be hindered by present policies. The smaller farms do not benefit much from traditional commodity programs. These factors have changed the public's perception about agriculture and raised questions about the objectives of farm programs and who benefits from them.

At prices near or above recent support levels, demand for U.S. agricultural products is unlikely to be strong through the decade of the 1980's. There is also growing awareness of the importance of price in world markets. How the Nation chooses to reconcile this issue (the objective of maintaining farm income on the one hand and expanding exports on the other) is critical to the character of U.S. agriculture in the rest of the century. These choices will determine not only price levels and how they are set, but also who will produce and where.

Domestic farm policy tends to drive agricultural trade policies. Further, domestic farm policy is becoming more closely linked to resource and environmental policies. Agricultural programs may influence the long-term use, availability, and productivity of soil and water resources. Production inputs may affect the safety of products and influence the quality of resources for those who use them directly. Agricultural production is influenced by industrial pollution, such as acid rain. Thus, lawmakers are becoming sensitive to these multiple interests and their implications, and to the linkages between various domestic policy tools.

Research programs are needed to:

- Evaluate emerging policy issues in the broadest possible context. Agricultural policy is no longer in a separate arena. Information is needed on the impacts of alternative policy options on producers, consumers, soil and water resources, foreign trade, and the environment.

Extension programs are needed to:

- Inform producers and the general public on policy implications in order to stimulate informed citizen involvement in the public policy process.
- Provide information to the public in order to enable individuals and businesses to make practical business decisions in view of policy changes.

Improve Economic Information on U.S. Agricultural Trade

Although today the United States is competitive in world markets for most of its agricultural and forestry exports, its future competitive position and comparative advantage are in question. Comparative advantage is a dynamic concept. It is affected by national policies and by investments in human resources, research and development, natural resources, and marketing and transportation. From a domestic perspective, the issue concerns the ability and willingness of the United States to make appropriate investments to maintain and enhance the competitiveness of its agricultural products in world markets. A related issue concerns the ability of the United States to be competitive in exporting value-added agricultural and wood products.

Many countries protect their agricultural producers from price variability in international commodity markets. Agricultural price and income support programs often result in supply conditions that cause the imposition of import barriers, export subsidies, production controls, stocking programs, or some combination of these to balance quantities produced with quantities used and influence agricultural trade patterns. These policies cause more variable world market prices for agricultural products. As a result, U.S. producers with big stakes in export outlets face highly variable market conditions.

Agricultural trade patterns are influenced by import barriers, export subsidies, production controls, stocks management, and related trade policies. To what extent do these policies restrict the pursuit of comparative advantage? What U.S. trade strategies will minimize the effect of the trade policies of other countries? Will a domestic stocks policy provide a sufficient buffer against shocks in trade patterns? Which sector of the economy, and who among the trading partners, should bear the costs of programs to promote trade stability?

Two important issues result from policy-induced world price variability: (1) how and by whom shall costs of adjusting to instability be borne? and (2) what measures will be most effective in moderating the fluctuations in agricultural prices and supplies? The United States may need new or altered policies and programs to deal with international trade problems. Stocks management will be an important component of policies to deal with instability. These and other issues must be addressed in the context of domestic commodity and trade policies as well.

Research programs are needed to:

- Monitor changes in the global conditions that give rise to price variability—such as weather, domestic policies, world stock levels, trade barriers, and trade agreements—and improve the forecasting of developments in world agricultural supply, demand, and trade.

- Improve and extend foreign country data and information on the technical, economic, and institutional variables that affect costs of production, comparative advantage, and competitiveness. These data will permit improved long-range projections of world supply and trade of agricultural and forestry commodities.

- Increase the potential for the production and export of higher valued agricultural and forestry products.

Extension programs are needed to:

- Improve producers' knowledge about the international markets for their commodities, including the availability of monitoring and outlook information on world production and prices, so they can improve the timing of their marketing activities.

Expand Domestic and International Markets for Agriculture and Forest Products

Market expansion is vital to the welfare and prosperity of American farmers and to the U.S. economy. Growing markets maintain national employment, restrain inflation, and improve our balance of payments. The growth of American food, fiber, and forestry industries depends on their ability to sustain improvements in productivity, efficiency, and product quality and increase output in line with demand. Lagging productivity and efficiency contribute to higher prices for agricultural products, declining markets, and a loss of U.S. jobs. Labor-intensive production and processing are shifting to other countries with lower wage rates. Market development needs to focus on new products and new uses for agricultural products. Consumer attitudes and preferences, both domestic and foreign, affecting the consumption of farm products need to be explored and satisfied to expand demand.

Foreign trade in agricultural and forestry products expanded greatly during the 1970's. Spurred by favorable prices and growing demand, American farmers increased their investment in production facilities to take advantage of this market opportunity. Production from one out of every three U.S. acres now goes to foreign markets. During the last 15 years, the surplus from agricultural trade has provided foreign exchange to help pay for imports of petroleum, other raw materials, and consumer goods. It also has contributed to U.S. world political and economic leadership, sustained incomes and employment in agriculture and related industries, and held down costs for farm price and income supports.

Agricultural exports have dropped more than 20 percent since 1981, partly because of the high value of the dollar in foreign trade. Financial problems and improved food production in many countries—particularly developing countries—contributed to the decline. The decrease in farm exports has reduced farm incomes, increased the cost of government price and income support programs, revived trade conflicts, and renewed a shift toward protectionism.

To expand domestic and foreign markets for the U.S. farm products, research and education programs are needed to:

- Improve the efficiency and competitiveness of producing, processing, and distributing agricultural and forest products.

- Improve post-harvest handling, processing techniques, product development, and marketing strategies that will lead to more value-added products and increased market penetration.
- Develop new uses, new processes, and new products that are more acceptable to domestic and foreign consumers.
- Improve the understanding of the effects of international economics, alternative trade policies, trade barriers, monetary policy, exchange rates, and world supply and demand on international trade and their impact on private and public decisions on trade policy.
- Improve the development and coordination of research and information systems to link production and marketing more closely with consumer demands and marketing requirements.
- Encourage the continuing efforts of government agencies, universities, and the private sector in promoting economic development in developing countries to expand the future market potential for U.S. agricultural products.

Increase Public Education on Agriculture

The largely urban U.S. society has little appreciation for the difficulties involved in a biological food and fiber production system dependent on weather, diseases, insects, and other natural variables. Nor are citizens concerned about whether the financial, business, and regulatory environment will result in an efficient, progressive, and productive agricultural sector. The public has a low level of understanding and support for the changing economic, institutional, and political settings for the production and marketing of agricultural products here and abroad.

The U.S. food and fiber system is under substantial pressure to adjust to changing national and international conditions. Those who serve agriculture in private business and public positions live and work in an increasingly complex system of laws and regulations. Further complicating the area of agricultural policy is increasing intrusion from other sectors on regulatory issues such as environmental quality, employee safety, trade practices, and food labeling.

U.S. citizens need a better understanding of agriculture and its related industries and of the consequences of alternative agricultural policies so they can participate more effectively in setting those policies. The agricultural science and education system must develop and implement an agricultural policy education program that will:

- Bring about an awareness that agriculture is our most basic and important industry.
- Increase citizen understanding of the interrelation and interdependence of farmers, industry, and government in bringing high-quality, low-cost food, fiber, and forest products to consumers.

- Generate public understanding and support for the role of food and agriculture in the U.S. society and economy.

- Raise the awareness of impacts of international trade on agriculture and our domestic economy.

- Disseminate useful and timely information on challenging issues of public concern such as water pollution, pesticide use, agricultural waste disposal, groundwater quality, and food quality and safety.

Develop Volunteer Leadership

The effectiveness and efficiency of the Extension education system are enhanced by the time, effort, enthusiasm, skills, talents, and commitment of local volunteers. Volunteers continue to make educational programs highly cost-effective by their leadership and assistance in identifying needs, teaching and sharing information, extending program capabilities and resources, and working with local organizations and community projects. Through proper recruiting, training, and utilization of volunteers, Extension can, in part, offset declining public investment while continuing to maintain or expand program benefits.

A recent national study on the Implications of Volunteerism in Extension showed that in 1983 some 2.9 million volunteers spent more than 71 million days helping 48.7 million people in their communities. Volunteers invested 51 days of service for each day spent by an Extension agent in support of volunteers. If communities had paid for volunteers' services, the bill would have been more than $4.5 billion—five times greater than the total budget for the Cooperative Extension Service. A 10 percent improvement in volunteer management efficiency could contribute a $450 million increase in services to Extension clientele.

The science and education community must continue volunteer management and development programs that recruit, train, assist, and utilize volunteers in advising, planning, implementing, and evaluating programs. Special emphasis is needed to:

- Increase volunteer participation in master teacher and middle management roles and expand overall program participation.

- Initiate and expand representation and services to limited resource and hard-to-reach clientele and expand efforts to secure greater participation of these groups as volunteers.

- Teach volunteers skills that enhance their employability.

- Expand use of volunteers so that professionals can focus more time on training and on managing educational programs.

Expand Use of Electronic Communications/ Computer Systems

New knowledge and technological developments in the food and agricultural sciences are not utilized quickly enough for maximum effectiveness. Most individual information users do not have the ability to use computers and other new communication technologies. Yet, they must integrate information, knowledge, and techniques from the numerous disciplines into cohesive, flexible, and economical operating systems. Extension professionals and volunteers are not trained to use electronic communications systems effectively with youth and adults to improve the rate of technology transfer, obtain information, and make priority decisions related to agriculture.

It is important to accelerate the use of this rapidly advancing field of communications technology, so that all conveyors and users of food and agriculture information will benefit from the use of rapid, modern information delivery systems.

Research is needed to:

- Develop, test, and implement computerized decision-aid models to assist in knowledge integration.
- Develop an easily accessible, electronic, informational resource to speed the transfer of knowledge and increase the rate of adoption of new technology.
- Explore the use of other communication technologies such as interactive teleconferencing and satellite delivery to expand program delivery capacity.

Extension programs are needed to:

- Equip and train extension personnel to utilize communication technologies and computer systems and integrate them into their educational programs.
- Provide a software development and evaluation system to ensure that accurate, reliable, and useful educational and decisionmaking aids will be available.
- Expand programs on computers, networks, and other new communications technologies for improved decisionmaking.
- Develop informational data bases and make them available through public and private-sector networks to serve as up-to-date, state-of-the-art information resources.

Appendix 3

Members of the Joint Council on Food and Agricultural Sciences

ANDERSON, James H. (Cochair)*
Vice Provost and Dean, College of Agriculture and Natural Resources
Michigan State University
East Lansing, MI 48824

BENTLEY, Orville G. (Cochair)*
Assistant Secretary
Science and Education
U.S. Department of Agriculture
Room 217-W, Administration Building
Washington, D.C. 20250

BUCKMAN, Robert E.
Deputy Chief for Research
Forest Service
U.S. Department of Agriculture
Room 3007, South Building
Washington, D.C. 20250

CARTER, Lark P.
Dean, School of Agriculture
California Polytechnic State University
San Luis Obispo, CA 93407

COULTER, K. Jane
Director, Higher Education Programs
Agricultural Research Service
U.S. Department of Agriculture
Room 350-A, Administration Building
Washington, D.C. 20250

CURTIN, Terrence M.
Dean, School of Veterinary Medicine
North Carolina State University
Raleigh, NC 27650

EDWARDS, Jeanne W.
Users Advisory Board Representative
240 Westerly Road
Weston, MA 02193

FISCHBACH, Andrew M.
Box 159
Faith, SD 57626

GREENWOOD, Mary Nell
Administrator, Extension Service
U.S. Department of Agriculture
Rm. 340-A, Administration Building
Washington, D.C. 20250

HOWARD, Joseph H.
Director, National Agricultural Library
U.S. Department of Agriculture
Rm. 109-A, NAL Building
Beltsville, MD 20705

HURST, Robert L.
Vice President for Research & Extension
South Carolina State College
P. O. Box 1765
Orangeburg, SC 29117

JOHNSRUD, Myron D.
Director, Cooperative Extension Service
North Dakota State University
Fargo, ND 58105

JORDAN, John Patrick
Administrator, Cooperative State Research Service
U.S. Department of Agriculture
Rm. 304-A, Administration Building
Washington, D.C. 20250

KENDRICK, Edgar L.
Administrator, Office of Grants and Program Systems
U.S. Department of Agriculture
Room 324-A, Administration Building
Washington, D.C. 20250

KINCAID, David R.
Director, International Research Division
Office of International Cooperation and Development
U.S. Department of Agriculture
Room 4200, Auditors Building
Washington, D.C. 20250

KINNEY, Terry B.
Administrator, Agricultural Research Service
U.S. Department of Agriculture
Room 302-A, Administration Building
Washington, D.C. 20250

LEE, J. Charles
Head, Department of Forest Service
Texas A&M University
College Station, TX 77843-2135

LEE, John E.
Administrator, Economic Research Service
U.S. Department of Agriculture
Room 448, GHI Building
500 12th Street, S.W.
Washington, D.C. 20250

LITTLE, C. Oran
Associate Director
Experiment Station
University of Kentucky
Lexington, KY 40546-0091

LUCK, John V.
Senior Vice President
General Mills, Incorporated
James Ford Bell Technical Center
9000 Plymouth Avenue North
Minneapolis, MN 55427

LUND, H. Roald*
Dir., Agricultural Experiment Station
North Dakota State University
Box 5435, State University Station
Fargo, ND 58105

MAWBY, Russell G.*
Chief Executive Officer
W. K. Kellogg Foundation
400 North Avenue
Battle Creek, MI 49016

MOLINE, W. J.*
Director, Cooperative
Extension Service
University of Arkansas
P. O. Box 391
Little Rock, AR 72203

MYERS, Peter C.
Assistant Secretary,
Natural Resources and
Environment
U.S. Department of Agriculture
Room 242-W, Administration
Building
Washington, D.C. 20250

OWEN, Robert R.
President, The Eversman Mfg.
Company
1145 Fifth Street
P. O. Box 4345
Denver, CO 80204

OYER, Edwin B.
Director, International
Agriculture Program
Cornell University
Ithaca, NY 14853-0332

SLEDGE, George W.
Associate Dean and Director
Academic Affairs
College of Agricultural & Life
Sciences
University of Wisconsin
Madison, WI 53706

TREAT, Kathryn R.
Assistant Director
Cooperative Extension Service
New Mexico State University
Las Cruces, NM 88005

WALKER, Melvin E.
Research Director
Division of Agriculture
Fort Valley State College
P. O. Box 5744
Fort Valley, GA 31030

WEFALD, Jon
Chancellor
Minnesota State University System
230 Park Office Building
555 Park Street
St. Paul, MN 55103

YOUNG, Alvin
Senior Policy Analyst
Office of Science and Technology
Policy
Room 5005, New Executive Office Bldg.
Washington, D.C. 20500

Executive Secretary to the Joint Council

MILLER, Larry R.
Joint Council on Food and
Agricultural Sciences
U.S. Department of Agriculture
Room 321-A, Administration
Building
Washington, D.C. 20250

*Members of the Executive Committee

Appendix 4

References[1]

Bolen, K. R. and L. E. Lucas. 1984. Regaining Farm Profitability in America. A Cooperative Extension System Response for the Extension Committee on Organization and Policy. Produced by the Department of Agricultural Communications, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NB. 18pp.

Congress of the United States, Office of Technology Assessment. 1985. Technology, Public Policy, and the Changing Structure of American Agriculture. A Special Report for the 1985 Farm Bill. OTA-F-272, March 1985, Washington, D.C. 122pp.

Hill, Gideon D. 1984. Research Planning To Address New Challenges in Agriculture With Constant Resources: An Industry Viewpoint. Proceedings, Agricultural Outlook Conference, December 3 - 5, 1984, p. 238-246, USDA, Washington, D.C.

Johnson, G. L. and S. H. Wittwer. 1984. Agricultural Technology Until 2030: Prospects, Priorities, and Policies. Michigan State University Agricultural Experiment Station Special Report 12. 61pp.

National Academy of Sciences, National Research Council. 1985. New Directions for Biosciences Research in Agriculture. High Reward Opportunities. National Academy Press, Washington, D.C. 122pp.

National Agricultural Research and Extension Users Advisory Board. 1985. Appraisal of the Proposed Budget for Food and Agricultural Sciences. Report to the President and Congress. February 1985, Washington, D.C. 54pp.

U.S. Department of Agriculture, Economic Research Service. 1985. The Current Financial Condition of Farmers and Farm Lenders. Agricultural Information Bulletin No. 490, March 1985. 34pp.

U.S. Department of Agriculture, Science and Education. 1984. Research Background for 1985 Farm Legislation. Washington, D.C. 59pp.

[1]These are selected references used as background information and are not cited in the text.

United States
Department of
Agriculture

Agricultural
Research Service

The Mission of the Agricultural Research Service

FOREWORD

This document states the mission of the Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA). It also describes the specific scientific activities through which ARS pursues that mission in three contexts.

As one component in the full U.S. agricultural research and development system, ARS carries out research that is critical for maintaining the vitality and productivity of the Nation's food and agricultural industries. There is valid consensus that the current strength and well-being of those industries have resulted from, and will continue to rely on, effective research.

As the research arm of the USDA, ARS responds to the needs of the vast complex of interactive industries that produce, process, and deliver agricultural products to consumers in the United States and around the world. The activities of ARS mirror that complex but are assembled in the agency in a way that efficiently supports the diverse and separate phases of agriculture.

As a Federal system of science laboratories, ARS provides an extensive network of research centers, locations, and work sites. They are strategically located in the geographic areas best suited for the pursuit of research on specific agricultural commodities and on specific problems. Many are near Land-Grant Universities and State experiment stations with whom ARS cooperates. In the ARS organization, research activities are decentralized, but they are centrally managed.

This document highlights some of the special capabilities that ARS has developed to meet the specific needs of agriculture and to solve its specific problems. The many statutes legislated since 1862 that have shaped ARS and to which ARS must respond are summarized in Appendix A.

The Agricultural Research Service, its programs, and its employees reflect the dynamic nature of the complex that is U.S. agriculture. The enviable record of U.S. agriculture is a tribute to the generations of scientists who have contributed to every area of research included in their mission. Specific objectives in that mission have changed during the last 20 years and will continue to change. Overall, however, the sole mission of ARS, the world's largest and most diverse national research organization, is research that responds promptly to the changing needs of U.S. agriculture.

T. B. Kinney, Jr.

T. B. KINNEY, JR.
Administrator
Agricultural Research Service
U.S. Department of Agriculture

CONTENTS

	Page
THE MISSION OF THE AGRICULTURAL RESEARCH SERVICE	1
SPECIAL CAPABILITIES OF THE AGRICULTURAL RESEARCH SERVICE	3
ORGANIZATION AND OPERATION OF THE AGRICULTURAL RESEARCH SERVICE	5
Administrator	5
Deputy Administrator, National Program Staff	5
Regional Administrators	6
ARS FACILITIES	7
Major National and Regional Centers	8
Human Nutrition Research Centers	10
Crop Sciences Facilities	12
Livestock and Veterinary Sciences Facilities	20
Postharvest Science and Technology Facilities	24
Soil, Water, and Air Sciences Facilities	29
APPENDIX A - PRINCIPAL STATUTES	31
APPENDIX B - AGRICULTURAL RESEARCH SERVICE OFFICES	45
APPENDIX C - MAP SHOWING MAJOR ARS LOCATIONS	47

Issued July 1982
Slightly revised January 1983

More specifically, ARS conducts research that is--

1. National in perspective in that it focuses on significant problems affecting the entire Nation or its several broad geographic areas;

2. Sufficiently long range, high risk, and of such broad scope as to require the unified planning, continuity of effort, and stable scientific environment maintained by the Federal research organization;

3. Not undertaken by other agricultural research institutions because of their narrower geographic focus or shorter term perspective; and

4. Uniquely a Federal responsibility in that it--

    a. Is requested by Congress or the Executive Branch and requires special skills, facilities, or capabilities of ARS;

    b. Requires a structure ready to respond to emergency situations of regional or national significance;

    c. Is international in nature, supporting foreign policy initiatives of the U.S. Government;

    d. Supports the development and maintenance of important national collections that are essential to scientific activities; or

    e. Supports Federal action programs.

SPECIAL CAPABILITIES OF THE AGRICULTURAL RESEARCH SERVICE

To accomplish its mission, ARS—

- Operates a complex organization that conducts research to achieve long-range objectives in agriculture, while ensuring dynamic, timely, and flexible responses to new problems and changing national goals;

- Maintains a network of research centers, locations, and worksites in the United States and abroad; and

- Encourages and nourishes a scientific environment that fosters the development of creative, innovative technical expertise.

The following are essential to the ARS mission:

A Centrally Organized Base of Scientific and Agricultural Expertise--The ARS national organization permits the quick formation and operation of multidisciplinary teams to respond to research needs. These teams are centrally coordinated and can be assigned to priority research or analysis of problems without conflicting demands on time or responsibility. The familiarity of ARS scientists with Government programs, action agency needs, and regional and national problems provides a unique overview perspective on the full agricultural research system.

Central Planning, Management, and Coordination--As a major component of the full research and development system, ARS centrally plans, coordinates, and manages diverse research programs that operate in a decentralized mode.

Unique Collections and Repositories--Unique collections and repositories of information and materials, developed and maintained by ARS, are essential in meeting national research needs and are heavily utilized by other public and private research organizations. They include the National Seed Storage Laboratory and other facilities for plant germplasm introduction and preservation; clonal repositories; disease-free seed stock; the ARS Culture Collection; and other taxonomic collections of plants, microbes, and insects.

Critical Mass of Scientific Talent--The diversity of its scientific work force allows ARS to assign critical masses of scientific talent to geographically broad problems not readily undertaken by State, private, or industrial institutions. Research teams can be established from ARS' own scientific resources and used in coordination with resources of the State agricultural experiment stations and other institutions. These teams can attain the critical mass that is vital to the interaction and stimulation needed for scientists to generate new ideas and resolve complex problems.

Extensive Resources Specific to Research in Agriculture--Much of ARS resources of expertise and facilities complements and supports other parts of the full agricultural research system. Its regional research centers are invaluable national resources; they are recognized internationally as premier agricultural research establishments. ARS has specialized facilities for research on exotic diseases of animals and plants and on the insect vectors of such diseases. It also has resources for implementing long-term, high-cost, high-risk research in facilities that other research organizations cannot establish or maintain. The reservoir of information and experience at ARS research centers is highly important to the continuity and progress of the full U.S. agricultural research and development system. In addition, ARS has the capability to develop scientists through its Office of Higher Education.

ORGANIZATION AND OPERATION OF THE AGRICULTURAL RESEARCH SERVICE

ARS is centrally managed by the Administrator, who is located at the USDA Headquarters in Washington, D.C. He is assisted in planning, budgeting, and managing the overall ARS program by the ARS National Program Staff (NPS), which is led by the Deputy Administrator. The Deputy Administrator is located at the Beltsville, Maryland, Agricultural Research Center. General performance of research is managed through four Regional Administrators who are responsible for activities in each of the four geographic regions shown in Appendix C. These regions roughly correspond to the four State agricultural experiment station regions. Each region operates under standard hierarchical management, and certain responsibilities are delegated to Area and Center Directors. Certain cross-cutting activities may be assigned to mid-level project managers.

Administrator

The Administrator is responsible for all ARS activities, including planning, executing and balancing programs, and deploying resources to achieve the objectives of the Agency. He formulates ARS policy and advises the Department on policy relating to national agricultural research matters. He has overall responsibility for coordinating ARS' planned activities with cooperators in the public and private sectors and with other Federal agencies served by ARS. He is responsible for assessing general program progress and evaluating broad program areas for performance in attainment of stated goals and objectives. He also represents ARS to the Assistant Secretary for Science and Education, the Secretary of Agriculture, and other such Cabinet- and sub-Cabinet-level Administrators with whom ARS interacts.

Deputy Administrator, National Program Staff

The Deputy Administrator serves as the leader of the NPS. He and his staff are the Administrator's chief technical advisers for national research programs and are responsible for the technical excellence of the national research programs. He and his staff have direct responsibility for leading budget development, coordination, review, and evaluation of ARS national programs to ensure proper interaction, balance, and distribution of research efforts focused upon national and major regional issues.

The Deputy Administrator and the NPS are responsible for--

- Providing national technical leadership of ARS programs;
- Establishing long-range goals, strategic and operational plans, and program priorities;
- Planning and conducting program reviews;

- Coordinating, monitoring, and evaluating national and regional programs;

- Maintaining coordination with scientists, administrators, and public and private cooperators on research and budget needs; and

- Providing liaison for ARS programs between ARS and the Federal, State, private, and public interactors with the ARS system.

Regional Administrators

ARS Regional Administrators are responsible for laboratory and field implementation of ARS' programs in their respective Regions in accordance with the Administrator's policies and the stated goals and objectives of the ARS Strategic Plan. They are responsible for implementing that part of the national operational plan that falls within their respective Regions and for ensuring that such implementations are in full agreement with the national plan. Regional Administrators, with the Deputy Administrator and NPS, provide counsel to the Administrator on policy issues and budget development. Regional Administrators serve as line managers for ARS program implementation through a hierarchy of Area and Center Directors and of Research Leaders at individual locations. They are responsible for program performance and resource management at the regional level.

The Regional Administrators and their Area and Center Directors--

- Direct and execute approved programs;

- Recruit, employ, evaluate, and make the best utilization of ARS scientists in keeping with national program needs and requirements;

- Participate with NPS in planning and conducting program reviews and in executing recommendations resulting from them;

- Approve annual reports and plans, as well as position resource management plans;

- Participate with NPS, through the ARS Budget Board, in developing the ARS budget; and

- Maintain coordination with State experiment station directors, regional councils, and other individuals and groups that have an interest in agriculture.

ARS FACILITIES

The ARS facilities for agricultural research are extremely diverse and unequaled throughout the world. Research is conducted at many centers, laboratories, and locations that range in size from small stations to the large 450-scientist facility at the Beltsville, Maryland, Agricultural Research Center.

Most facilities are owned and operated by ARS, but several locations are provided by the U.S. General Services Administration or are leased. Some locations are designed to address research problems that have a very specific focus. Other facilities, such as the Beltsville Agricultural Research Center, have a wide array of programs that are best addressed by a multidisciplinary approach and require equipment and facilities for many scientific disciplines and activities. ARS facilities are located throughout the United States and overseas so that problems of regional, national, and international nature can be addressed under the most favorable research environment. Many are located on university campuses and State agricultural experiment stations to assure cooperation and interaction with State scientists.

This type of arrangement encourages joint use of expensive research equipment, as well as of other essential facilities such as libraries, computers, and experimental plots. The following is a descriptive listing of ARS facilities grouped according to the following areas of agricultural research activity: Major National and Regional Centers; Human Nutrition Research Centers; Crop Sciences Facilities; Livestock and Veterinary Sciences Facilities; Postharvest Science and Technology Facilities; and Soil, Water, and Air Sciences Facilities.

Major National and Regional Centers

Beltsville Agricultural Research Center (BARC)--With more than 450 full-time scientists, BARC is the largest center of excellence for national agricultural research in the United States and, possibly, the world. More than 7,000 acres of land are intensively utilized for plant and animal research. The hundreds of buildings meet the many specialized needs of the research program and house highly specialized equipment such as the computerized calorimeter in the Energy Metabolism Laboratory. The National Agricultural Library, located on the Center's grounds, is an important resource for all scientists. The close proximity of BARC to the Nation's Capital, headquarters for many Government agencies that include action and regulatory agencies and numerous research institutions associated with agriculture, is unique. The Center provides a panorama of agricultural research for visitors from many agencies and from many nations.

BARC has many interdisciplinary research teams of scientists with expertise in all agricultural disciplines and nearly all commodities. The Center is in a unique position to assemble scientific resources to attack specific problems of national importance. In addition, BARC houses major national taxonomic collections of insects, fungi, seeds, nematodes, animal parasites, and rhizobia. These collections and their evaluations provide essential national services for other scientists, for industry, and for regulatory agencies. The Center is located in Beltsville, Md.

Regional Research Centers and the Richard B. Russell Agricultural Research Center--The four regional research centers, together with the Richard B. Russell Agricultural Research Center, comprise a resource unmatched throughout the world. Each center represents a unique concentration of scientists with specialized scientific knowledge and of highly specialized instrumentation and equipment essential to conducting the basic and applied research needed to solve complex agricultural problems. Nearly 600 scientists are located at these five centers.

Each center has the scientific and engineering expertise necessary to respond to emergency needs of national or regional importance and to provide the continuity of effort required to conduct long-term basic research. The centers are especially capable of dealing with problems associated with postharvest technologies critical to the delivery of high-quality, nutritious, and safe food and fiber to consumers. Thus, the centers bridge the gaps among the interests of agriculture, industry, and consumers. The facilities are the Eastern Regional Research Center, Wyndmoor, Pa.; Northern Regional Research Center, Peoria, Ill.; Southern Regional Research Center, New Orleans, La.; Western Regional Research Center, Albany, Calif.; and Richard B. Russell Agricultural Research Center, Athens, Ga.

National Arboretum--The U.S. National Arboretum, established by an Act of Congress on May 4, 1927, comprises 444 acres in Washington, D.C. The Arboretum is a research institution for trees and other ornamental plants. Its work includes the improvement of plants through introduction, breeding, and selection. In 1973 the Arboretum was placed on the National Register of Historic Places.

The Arboretum has a major herbarium containing 500,000 botanical specimens for research and plant identification, and it publishes botanical findings and provides technical information to the public. In addition, it exchanges seed and plant material with other scientific institutions throughout the world to provide researchers with needed genetic resources and to enrich the educational collections displayed at the Arboretum.

Although not a park in the usual sense, the Arboretum provides ample opportunity for observing and enjoying plants. It has a steady flow of visitors--including scientists, landscape architects, gardeners, school children, and tourists--from around the world. As many as 20,000 people a day may visit the grounds and displays. The Arboretum is located in Washington, D.C.

Human Nutrition Research Centers

Human nutrition research is conducted at five research centers. Each has specific goals and objectives.

Beltsville Human Nutrition Research Center--The center at Beltsville, Md., plans and conducts research related to nutrient requirements for proteins, carbohydrates, lipids, vitamins, and minerals for optimal health and disease prevention. Research activities are associated with--

- Composition of foods containing the nutrients required by and biologically useful to humans; and
- Human requirements for proteins, carbohydrates, energy intake, lipids, minerals, and vitamins; and with the identification of the forms of these nutrients in various foods.

Grand Forks Human Nutrition Research Center--The center at Grand Forks, N. Dak., plans and conducts research related to human nutrient requirements, with emphasis on trace minerals. Research activities are associated with--

- Nutritional requirements for zinc, nickel, copper, and other minor elements and their relationships to optimal health, function, and performance;
- Physiological and biochemical factors that influence requirements for minor elements in all age groups; and
- Biological availability of minerals and the effects of nonnutritive factors in foods on availability of minerals.

Children's Nutrition Research Center at Baylor College of Medicine--The center, at Houston, Tex., plans and conducts research to develop a scientific basis for standards of nutrient intake and assessments of nutritional status. Research activities are associated with--

- Nutrient requirements in infants, children, and pregnant and lactating women;
- Relationships between nutrition and physical and mental development; and
- Role of diet in optimum growth and development.

Human Nutrition Research Center on Aging at Tufts University--The center at Boston, Mass., plans and conducts research on

nutrient needs of the elderly and the relation of dietary factors to the aging process. Research activities are associated with--

- Nutritional needs for optimal health, function, and performance throughout life; and

- Nutritional requirements in the aging population.

Western Human Nutrition Research Center--The center at San Francisco, Calif., plans and conducts research related to intervention programs and nutritional requirements. Research activities are associated with--

- Factors resulting in suboptimal nutritional status;

- Reliable, efficient, and inexpensive methods for defining nutritional status;

- Human nutritional requirements; and

- Nutritional criteria for designing and evaluating intervention programs.

Crop Sciences Facilities

Aquatic Weed Research Laboratories--Multidisciplinary teams that include weed scientists, plant physiologists, biochemists, chemists, soil scientists, entomologists, plant pathologists, ecologists, marine biologists, and others cooperate to develop ecological, mechanical, biological, chemical, and integrated management systems for the control of aquatic weeds in irrigation systems, drainage canals, water reservoirs, farm ponds, and other aquatic sites. Greenhouses, controlled-growth phytotrons, experimental ponds, model irrigation systems, and quarantine and other unique facilities are available for evaluating fish, insects, plant pathogens, snails, mammals, other biological organisms, selective chemicals, and water management as means of controlling aquatic weeds. Cooperating with ARS in these efforts are other Federal agencies, State agricultural experiment stations, and industrial organizations that generally do not maintain research staffs and facilities for research on aquatic weeds. The facilities are located at the Aquatic Weed Control Research Laboratory, Fort Lauderdale, Fla.; Southern Weed Science Laboratory, Stoneville, Miss.; Weed Control Research Laboratory, Prosser, Wash.; and Aquatic Weeds Control Research Laboratory, Davis, Calif.

Barley and Malting Quality Laboratory--This laboratory, which has unique facilities for determining malting quality, serves Federal and State research programs in the North Central, Mississippi Valley, and western barley-growing regions. Specialized facilities for studying the biochemistry of malting are provided to serve these projects, as well as to investigate basic processes involved in malting. The laboratory is located in Madison, Wis.

Bee Research Laboratories--In these ARS laboratories, a critical mass of scientists with special expertise work on pollination problems of importance to the whole country. These facilities are equipped with specialized support buildings and cages. For example, isolation is required so that large numbers of normal and specialized bee colonies can be maintained near the laboratories. Facilities are located at the Honey Bee Pesticides and Disease Research Laboratory, Laramie, Wyo.; Bee Breeding and Stock Center, Baton Rouge, La.; Carl Hayden Bee Research Center, Tucson, Ariz.; Wild Bee Biology and Systematics Research Laboratory, Logan, Utah; Bioenvironmental Bee Laboratory, Beltsville, Md.; and Bee Management Laboratory, Madison, Wis.

Biological Control Research and Quarantine Facilities--These laboratories house specialists experienced in foreign and domestic field or laboratory studies of exotic beneficial organisms that may be used to control pest insects, pathogens, and weeds. The concentration of expertise in a few, highly secure quarantine facilities where research can be done safely produces an excellent environment for conducting fundamental and applied research. These facilities are used by State departments of agriculture, State agricultural experiment

stations, USDA's Animal and Plant Health Inspection Service, USDA's Forest Service, and other organizations that wish to actually release organisms in the field. Facilities are located at the Plant Disease Research Laboratory, Frederick, Md.; Delta States Research Center, Stoneville, Miss.; Beneficial Insects Research Laboratory, Newark, Del.; Biological Control of Weeds Laboratory, Albany, Calif.; Biological Control of Insects Research Unit, Columbia, Mo.; Biological Control of Insects Laboratory, Tuscon, Ariz.; Biological Control of Weeds Research Laboratory, Buenos Aires, Argentina; European Parasite Laboratory, Sevres, France; Biological Control of Weeds Laboratory, Rome, Italy; and Asian Parasite Laboratory, Seoul, Korea.

Cereal Disease Laboratories--These two laboratories have specialized facilities for investigating the behavior of major cereal diseases of national scope. The laboratories maintain national oversight of the epidemiology of major cereal diseases, conduct and maintain national surveys of disease races, and investigate the basic genetics of disease resistance. The facilities are located at the Cereal Rust Laboratory, St. Paul, Minn., and the Corn Virus Research Laboratory, Mississippi State, Miss.

Cotton Research Laboratories--These four laboratories are located in production regions that differ in soil type, climate, water management, and pests. At each location, teams of 9 to 16 geneticists, agronomists, physiologists, and plant-protection scientists work together to develop improved cotton production systems. Facilities are located at the ARS Western Cotton Research Laboratory, Phoenix, Ariz.; U.S. Cotton Research Station, Shafter, Calif.; Cotton Insects Research Laboratory, Brownsville, Tex.; and Cotton Research Laboratories, College Station, Tex.

Crop Commodity Insect Control Research Facilities--These facilities provide locations where a critical mass of scientists--entomologists, plant breeders, geneticists, plant physiologists, chemists, engineers, and others--can cooperate in efforts to develop tactics, strategies, and systems that may reduce losses of major commodities to insect pests. These concentrations of personnel permit the effective use of rearing facilities, greenhouses, and specialized equipment. In addition, they facilitate the interdisciplinary research required to solve complex pest-management problems of national importance. Facilities are located at the Cotton Insects Physiology Research Unit, Baton Rouge, La.; Cotton Insects Research Laboratory, Brownsville, Tex.; Southern Grain Insects Research Laboratory, Tifton, Ga.; Northern Grain Insects Research Laboratory, Brookings, S. Dak.; Citrus Insects Research Laboratory, Weslaco, Tex.; Fruit and Vegetable Insects Research Laboratory, Vincennes, Ind.; Yakima Agricultural

Research Laboratory, Yakima, Wash.; Subtropical Horticultural Research Station, Miami, Fla.; Boll Weevil Research Laboratory, Mississippi State, Miss.; Boll Weevil Eradication Research Laboratory, Raleigh, N.C.; and Boyden Entomology Laboratory, Riverside, Calif.

Crops Research Laboratories--These two laboratories are located in production regions that differ in soil type, climate, water management, and pests. The research is conducted on sugarbeets, forage, and range and is aimed at breeding and production practices and pest control. Multidisciplinary teams of 10 to 12 scientists include plant breeders, geneticists, agronomists, plant pathologists, physiologists, and nematologists. In addition to office-laboratory space, the facilities include greenhouses with growth chambers, temperature- and humidity-controlled chambers for sugarbeet storage, and special isolation chambers for pollination. Facilities are located in Ft. Collins, Colo., and Logan, Utah.

Forage-Range-Livestock Research Stations--These five ARS stations are located in different production regions. Soil type, plant and animal species, climate, and other environmental factors interact to create unique agricultural production situations of national importance. At each location, teams of 4 to 10 scientists of many disciplines--breeders, geneticists, physiologists, agronomists, range and animal scientists, pathologists, and entomologists-- interact to solve problems and to increase production of forage and livestock from grasslands. These teams also work closely with scientists of other research agencies. Facilities are located at the U.S. Regional Pasture Research Laboratory, University Park, Pa.; North Central Dairy Forage Research Center, Madison, Wis.; U.S. Southern Great Plains Field Station, Woodward, Okla.; Squaw Butte Research Station, Burns, Oreg.; and Jornada Experimental Range Management Station, Las Cruces, N. Mex.

Fruit and Nut Crop Repositories--These repositories have been specifically located and maintained to provide vegetatively produced plant germplasm for U.S. scientists and are the first two of several planned. The Oregon repository maintains pome fruits, small fruits, filberts, hops, and mint. The California repository maintains stone fruits, grapes, walnuts, almonds, and certain minor crops. Involved are the collection, propagation, maintenance, and preliminary evaluation of such crops. These repositories are managed by curators and provide public, industry, and private breeders and other plant scientists with germplasm needed for crop improvement programs. They are distinct and separate from breeders' working collections. Facilities include office-laboratory space, screenhouses, greenhouses, isolation field plots, and temperature- and humidity-controlled storage chambers. The repositories are located in Corvallis, Oreg. and Davis, Calif.

Insect Attractants, Behavior, and Basic Biology Research Laboratory--The research at this laboratory is basic to management of insect pests of crops, stored products, and humans. The facility is unique because it is suitable for basic research on most processes of insect growth and development and of insect reception and response that are now believed to be the key to ecologically sound, selective, and safe methods of insect pest management. Unique instrumentation and skills have enabled the laboratory to solve problems for which solutions previously appeared to be difficult; for example, identifying and synthesizing attractants of serious insect pests. As a result, attractant pheromones for the Japanese beetle and for peach tree borers are now in commercial use. Behavioral and bioengineering research have yielded concepts and techniques that have been adopted to assure the quality of mass-reared sterile screwworms, Mediterranean fruit flies, and other insects. The use of pheromones and insect growth regulators to protect stored peanuts and other agricultural commodities has been developed to the pilot stage. The laboratory is located in Gainesville, Fla.

Mayaguez Institute of Tropical Agriculture--The mission of this institute is to aid continental U.S. agriculture by providing winter nurseries that permit year-round outdoor experimentation and development; to introduce, evaluate, select, multiply, preserve, and develop tropical crop germplasm of interest to U.S. agriculture; to aid the agriculture of Puerto Rico by conducting carefully selected cooperative studies; and to contribute to the development of agriculture in the tropics. The institute consists of one major building and 34 smaller support buildings on 207 acres of land adjacent to the University of Puerto Rico. In addition, a 125-acre farm, located about 25 miles north of Mayaguez at Isabela, consists mainly of experimental plots that include winter nursery operations. The institute provides an ideal location for a unique collection of subtropical and tropical plant germplasm. The institute is located in Mayaguez, P.R.

Metabolism and Radiation Research Laboratory--This national laboratory was established in 1964 to investigate the fate of pesticides, drugs, and other agricultural chemicals applied to crops, feeds, and livestock and to identify and explore insect vulnerabilities that can be exploited in managing insect pests. The laboratory has a highly trained interdisciplinary staff, unique equipment for irradiating insects, and an excellent collection of high-precision instruments for chemical analyses. The laboratory established, between wheat and wild oats, enzymatic differences that have been exploited by industry; established that diethylstilbestrol is stored in the livers of livestock; and discovered the first practical method of

sexually sterilizing boll weevils. The laboratory is located in Fargo, N. Dak.

National Seed Storage Laboratory--The National Seed Storage Laboratory, on the campus of Colorado State University, has been in operation since 1958. The mission of the laboratory is long-term preservation of valuable plant germplasm as viable seeds and research related thereto. Long-range studies focus on biochemical, physiological, and genetic changes in seeds during storage and the effects of seed moisture content, storage environment, and storage containers on seed longevity. Laboratory procedures for accurate monitoring of seed viability during storage are established on a crop-by-crop basis. Several million seeds, representing nearly 100,000 varieties, are stored in 11 cold-storage rooms. The laboratory is located in Ft. Collins, Colo.

Offshore Insect Control Research Facilities--ARS facilities in Hawaii and the Virgin Islands allow entomologists to conduct research and to produce experimental materials, such as sterile fruit flies, in isolated microcosms of mainland agricultural conditions. At the same time, the scientists can conduct research of direct benefit to these tropical and subtropical areas. These isolated locations form a unique national resource because they allow evaluation of procedures for managing pests that cause widespread damage to mainland crops and livestock. Facilities are located at the ARS Fruit Fly Laboratory, Honolulu, Hawaii; Hawaiian Agricultural Experiment Station, Hilo, Hawaii; and Federal Experiment Station, Kingshill, St. Croix, V.I.

Ornamental Plant Research Laboratory--This central laboratory was established to serve the needs of florists and nursery crop producers in the Pacific Northwest. The office-laboratory building is occupied by a multidisciplinary team of scientists consisting of plant pathologists, physiologists, an entomologist, an agronomist, and a soil scientist. The facility includes greenhouses, special isolation houses for pesticide research, and shade houses. Field work is conducted on nearby land leased from the State. The laboratory is located in Corvallis, Oreg.

Peanut Production, Disease, and Harvest Research Laboratory--This laboratory is located in the center of the Mid-Atlantic peanut production area. An interdisciplinary team of breeders, plant physiologists, and engineers work together to develop peanut production systems, applicable to the entire peanut production area, that will increase yield and improve product quality. The drying laboratory provides unique facilities for controlled studies of peanut drying. Work at this

facility is coordinated with work at other research institutions. The laboratory is located in Suffolk, Va.

U.S. Plant Introduction Station--This facility is the only USDA location for processing foreign plant germplasm that must be quarantined upon arrival in the United States. It is located in a nonagricultural area to ensure isolation of imported material, yet it is within a few miles of the Beltsville Agricultural Research Center and its available expertise.

Facilities include specially designed greenhouses and screenhouses for the maintenance of prohibited crop categories and foreign germplasm. Onsite expertise is available for performing indexing tests to detect a wide array of viruses, mycoplasmas, protozoa, spiroplasmas, and viroids. At the facilities are office-laboratory buildings that include 13 glasshouses, as well as cold rooms and specialized equipment. Plant varieties assembled on the grounds include 800 apple, 600 pear, 250 stone fruit, and 700 woody ornamental varieties. The station is located in Glenn Dale, Md.

Regional Plant Introduction Stations--These stations are located in the four geographic regions of the country for close cooperation with the State agricultural experiment stations. Each station is responsible for receiving, maintaining, increasing, distributing, and evaluating seeds of a specific array of crops and of potentially new crop species. These facilities are a key part of the national plant germplasm system, and they provide valuable national and international services to plant breeders, geneticists, and other scientists in the public and private sectors. Facilities are located in Experiment, Ga.; Ames, Iowa; Geneva, N.Y.; and Pullman, Wash.

Rice Research Laboratory--This laboratory is located on a State agricultural experiment station comprising nearly 1,000 acres. ARS scientists here study rice breeding, quality, diseases, drying after harvest, and storage insects. Onsite solar collectors and heat-storage units enable engineers to conduct pilot tests to improve rice drying with minimum energy inputs. The availability of more than 25 storage bins permits the study of rice-quality preservation over a period of several years. The ARS team effort encourages development of a quality-rice variety that will be resistant to plant diseases and postharvest insect attack. Because numerous commercial rice mills are located nearby, insect contamination of processed rice can be studied. The laboratory is located in Beaumont, Tex.

Subtropical Horticultural Research Station--This station is situated on 200 acres south of Miami. The staff consists of entomologists, plant pathologists, horticulturists, and an organic chemist. Research at the facility involves pest

control, reduction of marketing losses, and varietal and cultural improvement of subtropical plants. The station maintains unique germplasm collections of coffee, cacao, sugarcane, and other tropical and subtropical plants. The facility also provides for Federal and State cooperative programs on survey and detection of pests and on nursery inspection, postentry quarantine inspection, and development of coconut palms resistant to lethal yellowing disease. The station is located in Miami, Fla.

Sugarbeet and Vegetable Research Station--This facility serves the unique vegetable and sugarbeet production area of California's Salinas Valley and other production areas in the Western States. The valley opens to the ocean, making the location ideal for cool-season vegetables and sugarbeets. The facility includes an office-laboratory building, special greenhouses for isolation breeding, an electron microscope, a fully equipped agricultural engineering shop, and 100 acres of field plots. The station is located in Salinas, Calif.

Sugarcane Mechanization Laboratory--This facility provides shops and engineering laboratories that meet the space requirements for construction and testing of large field machines being developed for use in sugarcane production. The equipment developed at this facility is intended for use in both the Florida and Louisiana cane-production areas. Preliminary testing of new research concepts is conducted in ARS facilities, and field tests are conducted in State and privately owned fields. The laboratory is located in Belle Glade, Fla.

Sugarcane Research Laboratories--These two laboratories are located in sugar-production regions with different ecologies, soil types, water-management systems, diseases, insects, and cultural practices. Multidisciplinary teams include plant breeders, geneticists, agronomists, plant pathologists, plant physiologists, weed-control specialists, and entomologists. These locations have unique facilities, including large, tall, isolation-crossing houses with rail carts that move plants indoors at night, air-conditioned photoperiod houses, growth chambers, temperature- and humidity-controlled storage rooms, and sugarcane milling and harvesting equipment. Office-laboratory space is provided for 10 to 14 scientists. The facilities are located in Canal Point, Fla., and Houma, La.

Tree Fruit and Tree Nut Research Stations--Five regional research stations are located in production areas that differ in fruit-crop adaptation, soil type, climate, water management, and pests. Studies of tree fruit and tree nut crops differ by region and are conducted on citrus, apples, pears, peaches and other stone fruits, pecans, blueberries, and strawberries.

Teams of horticulturists, geneticists, pathologists, physiologists, entomologists, soil scientists, and agricultural engineers cooperate to develop new fruit and nut varieties and improved cultural systems. Scientific teams range from 4 to 18 scientists at the various locations. The research on perennial fruit crops is dedicated to long-range problems--research that is not easily initiated or justified by individual State agricultural experiment stations. The facilities are located at the Appalachian Fruit Research Station, Kearneysville, W. Va.; Production, Harvesting, and Handling of Tree Fruits, Wenatchee, Wash.; W. R. Poage Pecan Field Station, Brownwood, Tex.; Small Fruits Research Station, Poplarville, Miss.; Southeastern Fruit and Tree Nut Research Laboratory, Byron, Ga.; and U.S. Horticultural Research Laboratory, Orlando, Fla.

U.S. Delta States Agricultural Research Center--This research center emphasizes multidisciplinary, mission-oriented research in the basic and applied sciences, with the following objectives: Developing technology for improving crop production, harvesting, and processing efficiency; developing cost-effective technology for reducing crop losses caused by weeds, diseases, insects, and nematodes; improving environmental quality; and improving yields and quality of crops. Plant scientists, engineers, weed scientists, entomologists, plant pathologists, plant physiologists, chemists, nematologists, and soil scientists cooperate in contributing to these objectives.

Resources include controlled-growth phytotrons; greenhouses; research quarantine facilities for insects, plant pathogens, nematodes, and weeds; and large areas of land for field experiments. Research at the center is planned in cooperation with the States and industry to ensure emphasis on regional and national problems. The facility is located in Stoneville, Miss.

U.S. Vegetable Laboratory--This central facility was established as a regional laboratory to serve all of the Southeastern States for breeding, production, and protection of vegetable crops. It is located on 350 acres of prime vegetable cropland. It includes a large office and laboratory, a seed-storage building, special insect-rearing rooms, laboratories, vegetable-storage facilities, and several greenhouses. Scientists include geneticists, horticulturists, pathologists, agronomists, entomologists, nematologists, and a chemist. The Southeastern Forestry Research Laboratory is also located on the property, and a State substation occupies adjacent land. The facility is located in Charleston, S.C.

Livestock and Veterinary Sciences Facilities

Animal Disease Research Laboratories--The animal disease research efforts in ARS are concentrated at seven locations. One of these, the National Animal Disease Center in Ames, Iowa, is the largest such unit in the world and has a mission to conduct basic and applied research on diseases of national importance in cattle, sheep, swine, horses, and poultry The staff uses multidisciplinary approaches to solve animal health problems. The other animal disease laboratories are unique in that each specializes either in a single disease area or in specific diseases of a single animal species. The laboratories are located where a disease exists and where their scientists can readily collaborate with research scientists of other institutions. Chemists, virologists, bacteriologists, veterinarians, physiologists, entomologists, and pathologists work together on interdisciplinary approaches to disease control.

These ARS laboratories can conduct in-depth studies on economically important diseases that do not cause catastrophic losses and, therefore, often do not command continued support from State agencies or other Federal agencies. Because of their highly skilled staffs, the laboratories are excellent training locations for U.S. and foreign scientists who need specialized training. The large, interdisciplinary staffs also provide the United States with a highly trained research and diagnostic staff that can be mobilized rapidly to meet any animal disease emergency. Facilities are located at the National Animal Disease Center, Ames, Iowa; Arthropod-Borne Animal Disease Research Laboratory, Denver, Colo.; Animal Disease Research Unit, Pullman, Wash.; Southwestern Livestock and Forage Research Station, El Reno, Okla.; Regional Poultry Research Laboratory, East Lansing, Mich.; Southeast Poultry Research Laboratory, Athens, Ga.; and South Central Poultry Research Laboratory, Mississippi State, Miss.

Foreign Animal Disease Research Centers--ARS has unique responsibilities for research on animal diseases that do not exist in the United States but pose a continuous threat to U.S. livestock and poultry industries. The major portion of this research is conducted at the ARS laboratory on Plum Island, 1.5 miles off Long Island. One serious foreign disease being studied is foot-and-mouth disease which affects all farm animals except horses and poultry. By law the Plum Island laboratory is the only U.S. facility where this disease can be studied.

Another disease being studied extensively at the laboratory on Plum Island is African Swine Fever. No vaccine is available for this disease, which poses a serious threat to swine. Other foreign animal diseases that have been or are now being studied are rinderpest; contagious bovine pleuropneumonia; African

horsesickness; exotic strains of bluetongue; sheep pox; duck virus enteritis; Teschen disease of pigs; swine vesicular disease; and a serious blood-parasite disease called East Coast fever.

Under strict security regulations imposed by ARS and the Animal and Plant Health Inspection Service (APHIS), studies of fowl plague and exotic Newcastle disease are conducted by ARS at a laboratory in Athens, Ga. Another high-security facility for the study of insect-borne foreign diseases is located in Denver, Colo. A multidisciplinary team of veterinarians, microbiologists, immunologists, biochemists, electron microscopists, and pathologists develops research information that is essential in the diagnosis, prevention, control, and eradication of serious exotic diseases of animals that might gain entry into the United States. Facilities are located at the Plum Island Animal Disease Center, Greenport, N.Y.; Southeast Poultry Research Laboratory, Athens, Ga.; Arthropod-Borne Animal Disease Research Laboratory, Denver, Colo.; and Animal Disease Laboratory, Nairobi, Kenya.

Insects Affecting Livestock Laboratories--ARS research on insects affecting livestock is the largest single component of the U.S. effort to control insect pests. The work serves the livestock industry, which accounts for about half the cash income of American farmers. It also supports action programs of other agencies. For example, personnel are assisting in the screwworm eradication program being conducted by APHIS, in cooperation with Mexico, and plans have been made for future cooperative research with Canada's Agriculture Ministry to control the cattle grub. Other research is underway to support APHIS in efforts to control Texas cattle fever and cattle scabies.

The multidisciplinary teams of entomologists, chemists, immunologists, virologists, physiologists, and engineers at the several laboratories can be assembled and mobilized on short notice. They have the flexibility to conduct cooperative programs with APHIS, State agricultural experiment stations, and other governmental organizations on a regional, interregional, national, or international basis. Facilities are located at the Screwworm Research Laboratory, Mission, Tex.; Hemoparasite Disease Research Laboratory, Pullman Wash; Arthropod-Borne Animal Disease Research Laboratory, Denver, Colo.; Midwest Livestock Insects Research Laboratory, Lincoln, Nebr.; Livestock Insects Laboratory, Beltsville, Md.; Veterinary Toxicology and Entomology Research Laboratory, College Station, Tex.; Metabolism and Radiation Research Laboratory, Fargo, N. Dak.; Gulf Coast Mosquito Research Laboratory, Lake Charles, La.; U.S. Livestock Insects Laboratory, Kerrville, Tex.; Lone Star Tick Laboratory, Poteau, Okla.; Cattle Fever Tick Research Laboratory, Falcon Heights, Tex.; and Mayaguez Institute of Tropical Agriculture, Mayaguez, P.R.

Insects Affecting Man Laboratories--ARS research on insect pests of humans is the major such effort in the world. Most of the work is conducted in Gainesville, Fla., one of the largest and most specialized research facilities of its kind. Much of this work is conducted in support of the U.S. Department of Defense, which is concerned with preventing insect-borne diseases such as malaria, dengue, and encephalitis from reducing the efficiency of U.S. military personnel at home and abroad. In addition, personnel from the Gainesville laboratory serve as the technical nucleus for cooperative research with international organizations such as the United Nations and the U.S. Agency for International Development. A recent example of this type of cooperation was a project on the control of malaria-infectious mosquitoes in Central America.

The laboratory at Lake Charles, La., is strategically located for research on regional problems in support of APHIS programs. At both locations, the multidisciplinary teams of entomologists, epidemiologists, geneticists, and engineers can assist in instances in which State or local organizations may not have the desired expertise. Personnel serve as technical advisers to action agencies, such as APHIS, in times of disease outbreaks or vector-population explosions. Facilities are located at the Insects Affecting Man and Animals Research Laboratory, Gainesville, Fla.; Gulf Coast Mosquito Research Laboratory, Lake Charles, La., and Imported Fire Ant Research Laboratory, Gulfport, Miss.

Facilities for Research on Internal Parasites of Animals--The primary objective of the national parasite research program is to develop ways to prevent, control, or eradicate parasite infestations in livestock and poultry. The major unit in the program, the Animal Parasitology Institute, is the largest in the world devoted exclusively to research on parasites of food-producing animals. Parasitologists, veterinarians, chemists, entomologists, and immunologists cooperate in interdisciplinary approaches to achieve stated goals.

The ARS parasite research program provides for unbiased testing and evaluation of new antihelminthic drugs and proposed biological parasite control programs. The scientists also prepare and maintain two internationally known tools used by parasitologists worldwide: the Index Catalogue of Medical and Veterinary Zoology and the National Parasite Collection. Both are used nationally in studies of parasitism in livestock and poultry and are indispensable in efforts to develop parasite-control programs. Facilities are located at the Animal Parasitology Institute, Beltsville, Md., and the Regional Parasite Research Laboratory, Auburn, Ala.

Multidisciplinary Animal Production Research Centers--In addition to the major research effort at the Beltsville Agricultural

Research Center, ARS has several major research locations where large-scale research with dairy and meat-producing animals is conducted by multidisciplinary teams. Several of the research stations are the largest in the country, up to 56,000 acres in area, and their size enhances their ability to attract and retain high-quality scientists from many disciplines. The unique facilities and equipment range from sophisticated chambers for energy metabolism studies on individual animals to commercial-size production units for all classes of animals. The integrated programs conducted range from very basic research to studies in which large populations of animals are used in developing systems approaches to solve broad industry problems. Stations are strategically located to permit replicated studies in different physiographic situations to quantify interactions among genetic, nutritional, and management variables. Thus, programs of small stations become integrated parts of total programs and uniquely complement the programs of large stations.

Many of the large units are operated cooperatively with State agricultural experiment stations and serve as focal points for integrated research efforts, thereby enhancing the effectiveness of total research programs. In addition to the Beltsville Agricultural Research Center, Beltsville, Md., facilities are located at the U.S. Livestock Experiment Station, Miles City, Mont.; U.S. Sheep Experiment Station, Dubois, Idaho; Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr.; Southwestern Livestock and Forage Research Station, El Reno, Okla.; North Central Dairy-Forage Research Center, Madison, Wis.; and Brooksville Beef Cattle Research Station, Brooksville, Fla.

Poultry Production and Product Quality Laboratories--In addition to the poultry research programs at the Beltsville Agricultural Research Center, three major poultry-production and product-quality laboratories uniquely blend basic and applied studies using multidisciplinary team approaches. Interrelationships of the neuro-nutritional-endocrine systems are being investigated to improve turkey egg production. Unique cellular approaches are being used to study growth and the effect of stress on broilers. Agricultural engineers and poultry scientists are working on the effects of environment and management factors such as utilization of heat energy, limited area brooding, and control of environmental temperatures on the meat and egg production of chickens. Approaches being used to improve broiler product quality include investigating cage-rearing systems as a model for studying breast blisters and bone fragility; and studying ways to reduce the synergistic effects of several mycotoxins found in some feeds. Facilities are located at the Poultry Research Laboratory, Georgetown, Del.; Southeast Poultry Research Laboratory, Athens, Ga.; and South Central Poultry Research Laboratory, Mississippi State, Miss.

Postharvest Science and Technology Facilities

Animal Products Research Laboratories--Fundamental and applied research is conducted at nine laboratories across the Nation to evaluate and improve the quality and processing of animal products. Research conducted at one or more laboratories addresses processing, marketing, transportation, and distribution problems of meat, poultry, dairy products, freshwater fish, and eggs. Scientists study the biochemical, physiological, microbial, chemical, and physical changes in animals or their products during milking, egg collection, or transit, or after slaughter, and how these changes relate to genetic, production, or management practices or can be altered to protect or improve the quality and nutritional value of food produced from animals.

Techniques are developed for evaluating properties of tissues or products. Information is developed on biochemical/biophysical changes in animal tissues or products, and the mechanisms by which these are controlled or can be influenced become the basis for recommendations for maintaining and improving the quality of animal products. Knowledge of the effects of sodium on muscle protein solubility, meat emulsion stability, and the properties of muscle and milk protein could, for example, enable reduction in the amount of sodium added during processing. Research on animal products often requires an interdisciplinary approach to problems at a cellular and subcellular level. Such an approach involves food scientists, microbiologists, biochemists, physical chemists, and engineers. Often research supports Federal action agencies in their missions. Facilities are located at the Eastern Regional Research Center, Philadelphia, Pa.; Beltsville Agricultural Research Center, Beltsville, Md.; Richard B. Russell Agricultural Research Center, Athens, Ga.; Southern Regional Research Center, New Orleans, La.; ARS Bioengineering Research Laboratory, Columbia, Mo.; Northern Regional Research Center, Peoria, Ill.; ARS Transportation and Marketing Laboratory, College Station, Tex.; Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr.; and Western Regional Research Center, Albany, Calif.

Cotton Quality and Ginning Laboratories--These laboratories represent a research resource found nowhere else in the world. The specialized facilities and scientific staffs of the laboratories not only provide a valuable national resource for agriculture, but also support a major segment of the domestic textile industry and a sizable export market.

The Cotton Quality Research Station at Clemson evaluates the effects of proposed changes in the production/ginning sequence on the processing quality of cotton. The Southern Regional

Research Center is a central laboratory with instrumentation for evaluating small research samples of fiber and seed for cooperating ARS scientists at approximately 10 locations across the Cotton Belt. In addition, the laboratory provides analyses for the National Cotton Variety Testing Program conducted by ARS in cooperation with various State agricultural experiment stations. Together with the ginning laboratories, the two quality laboratories provide an essential research support service to the Cotton Division of USDA's Agricultural Marketing Service, which by law is responsible for grading and classifying the American cotton crop each year. The cotton quality facilities are located at the Cotton Quality Research Station, Clemson, S.C. and the Southern Regional Research Center, New Orleans, La.

Although all three ginning laboratories perform similar functions, each is essential to addressing the special genetic and harvesting problems pertaining to the three distinct cotton-growing regions of the United States: the humid, rainy areas of the Southeast and Mississippi Delta; the arid, High Plains of Texas; and the hot, dry, irrigated areas of the Southwest and West. Buildings and facilities are specially designed to handle, dry, and gin the seed cottons produced in these three separate regions of the Cotton Belt. The ginning facilities are located at the Southern Plains Cotton Research Laboratory, Lubbock, Tex.; Southwestern Cotton Ginning Research Laboratory, Mesilla Park, N. Mex.; and U.S. Cotton Ginning Laboratory, Stoneville, Miss.

European Marketing Research Center--The mission at this location is to conduct a research program that will contribute to increased efficiency in the marketing of U.S. agricultural products in Europe. Research is concerned with the identification and resolution of commodity quality problems, mainly in horticultural crops, that will reduce handling costs of and market losses in U.S. farm products. Facilities are located in Rotterdam, The Netherlands.

Family Resource Development Facilities--The Family Economics Research Group conducts research on the economic problems of families and the improved use of time, money, energy, and other resources by families. This group is located in Hyattsville, Md.

Scientists at the ARS Textiles and Clothing Laboratory conduct basic and applied research on the most effective use and care of textiles, clothing, and home furnishings available to consumers. The scientists disseminate research results in technical and popular publications. The laboratory shares a conditioning room with the Department of Textiles and Clothing at the University of Tennessee and, in addition to its own highly specialized textile-testing equipment, has access to

sophisticated equipment and instrumentation on the university campus. Facilities are located at the Textiles and Clothing Laboratory, Knoxville, Tenn.

Fruit and Vegetable Quality Research--Postharvest research is conducted at 12 locations throughout the United States where horticultural crops are produced, processed, and marketed. The laboratories conduct research on quality maintenance and loss reduction of horticultural crops and are located to provide direct access to growers, shippers, and receivers. To accomplish their mission, the laboratories study the effects of the preharvest environment unique to the growing area; effects of postharvest treatments for controlling pathological and physiological diseases; storage design, specifications, and environments; improved handling, packaging, and transporting methods; and chemistry and biochemistry of horticultural crops.

Research thrusts of some laboratories include energy conservation, waste reduction, and processing efficiency. Information is also developed for specifications and standards for raw and finished products. Facilities are located at the Agricultural Product Technology Research, Weslaco, Tex.; Fruit and Vegetable Chemistry Laboratory, Pasadena, Calif.; Citrus and Subtropical Products Laboratory, Winter Haven, Fla.; Food Sciences Laboratory, Raleigh, N.C.; Fruit and Vegetable Harvesting Research, East Lansing, Mich.; Red River Valley Potato Research Laboratory, East Grand Forks, Minn.; Market Quality and Handling Research Station, Miami, Fla.; Crop Protection and Production Research, Weslaco, Tex.; Market Quality and Transportation Research Laboratory, Fresno, Calif.; Production, Harvesting, and Handling of Tree Fruits Research, Wenatchee, Wash.; Commodity Treatment, Handling, and Distribution Research, Hilo, Hawaii; Horticultural Crops Quality Research, New Brunswick, N.J.; and Market Pathology Laboratory, Chicago, Ill.

Insect Control Laboratories--Ten insect control laboratories are distributed throughout the United States, so Federal scientists concerned with insect pests in stored commodities have access to the entire marketing system--from farm production to commercial storage, terminal export elevators, shipment and transportation, storage, milling, packaging, and overseas sales. These laboratories are equipped with chambers that can be used in commodity-treatment studies involving both vacuum and atmospheric test conditions. This equipment is generally not available anywhere else in the world.

Because of available laboratory facilities, investigations can proceed from studies at the basic level to studies on a scale large enough that practical problems can be identified and new

control techniques developed. Laboratory personnel include scientists, in various disciplines, in sufficient critical mass to facilitate interdisciplinary research. Facilities are located at the U.S. Grain Marketing Research Laboratory, Manhattan, Kans.; Stored Product Insects Research Laboratory, Fresno, Calif.; Hawaiian Agricultural Experiment Station, Hilo, Hawaii; ARS Fruit Fly Laboratory, Honolulu, Hawaii; Stored Product Insects Research and Development Laboratory, Savannah, Ga.; Tobacco Storage Insects Research Unit, Richmond, Va.; Insect Attractants, Behavior, and Basic Biology Research Laboratory, Gainesville, Fla.; Stored Product and Household Insects Laboratory, Madison, Wis.; Rice Experiment Station, Beaumont, Tex.; and Subtropical Horticulture Research Station, Miami, Fla.

Facilities for Research on Metabolic Safety of Agricultural Products--ARS programs constitute most of the Nation's research effort in the highly visible and increasingly important area of the metabolic safety of agricultural products. The required sophisticated equipment and facilities that could not be justified by smaller and less comprehensive units are concentrated in these facilities.

Specific objectives of the research are to (1) determine the metabolic fate of pesticides, agricultural chemicals, and drugs used to prevent and control diseases or to improve efficiency of animal production; (2) define chemical characteristics of and modes of action for and develop measures to prevent losses from poisonous plants and other naturally occurring toxicants; and (3) conduct toxicological and nutritional studies related to food and feed safety in production, processing, and distribution. Results are used by action agencies in programs to ensure the safety of animal products for consumers and to reduce the cost of production for producers. Facilities are located at the Beltsville Agricultural Research Center, Beltsville, Md.; Western Regional Research Center, Albany, Calif.; Richard B. Russell Agricultural Research Center, Athens, Ga.; Metabolism and Radiation Research Laboratory, Fargo, N. Dak.; Veterinary Toxicology and Entomology Laboratory, College Station, Tex.; and Poisonous Plant Research Laboratory, Logan, Utah.

National Peanut Research Laboratory--This laboratory, located in the heart of the Southeastern peanut production area, deals with problems associated with the quality and safety of peanuts. A multidisciplinary team, consisting of the essential scientific and engineering expertise needed to address problems in shelling, handling, grading, and storing of peanuts, provides a unique link among the farmer, small processor, and the food industry within the United States and abroad. The laboratory is located at Dawson, Ga.

U.S. Grain Marketing Research Laboratory--This laboratory provides the facilities, equipment, and critical mass of scientific and engineering expertise needed to address the full range of basic and applied research problems associated with maintenance of quality, reduction of losses, and safety in the handling and storage of grain. These capabilities are also used to resolve problems of the action agencies, particularly USDA's Federal Grain Inspection Service. This national facility complements the research capability of the milling school at Kansas State University and of the American Institute of Baking; together, they provide an unparalleled capability for resolving problems associated with our major agricultural commodities. The laboratory is located in Manhattan, Kans.

Soil, Water, and Air Sciences Facilities

Laboratories for Erosion and Sedimentation Studies--These laboratories have physical facilities--flumes, wind tunnels, raindrop towers, rain simulators, and field plots--that are unique for studying the physical processes involved in erosion, sediment transport, and sediment deposition. Multidisciplinary groups of scientists--engineers, soil scientists, chemists, agronomists, and biologists--work together to understand the processes involved in water and wind erosion, sediment transport, and sediment deposition and to develop methods for controlling erosion and sedimentation. Facilities are located at the National Erosion Research Laboratory, West Lafayette, Ind.; U.S. Big Spring Field Station, Big Spring, Tex.; and USDA Sedimentation Laboratory, Oxford, Miss.

National Tillage Machinery Laboratory--This laboratory is the only one in the United States in which soil bins and highly sophisticated instrumentation can be used to study the relationships among soil physical properties, tillage and traction devices, and machine performance. Studies are conducted on machine-mobility problems and on the effects of machine weights, traction, and flotation. The laboratory is located in Auburn, Ala.

Soil and Water Conservation Research Centers--These facilities are regional research centers that conduct soil and water conservation research applicable to the major land-use resource areas in which they are located. The facilities are federally owned and are located, in many instances, in areas where there are no universities. In some instances, cooperative efforts with State agricultural experiment stations are maintained. The centers are staffed with multidisciplinary teams, including soil scientists, agricultural engineers, plant physiologists, and agronomists, for research in broad problem areas. Some basic research is also conducted that has regional, national, and international significance. Facilities are located at the Appalachian Soil and Water Conservation Research Laboratory, Beckley, W. Va.; Plant, Soil, and Water Laboratory, Orono, Maine; North Central Soil Conservation Research Laboratory, Morris, Minn.; Northern Great Plains Research Laboratory, Mandan, N. Dak.; Central Great Plains Research Station, Akron, Colo.; Snake River Conservation Research Center, Kimberly, Idaho; Imperial Valley Conservation Research Center, Brawley, Calif.; Columbia Plateau Conservation Research Center, Pendleton, Oreg.; Soil and Water Conservation Research, Weslaco, Tex.; U.S. Southwestern Great Plains Research Center, Bushland, Tex.; Coastal Plains Soil and Water Conservation Research Center, Florence, S.C.; Southern Piedmont Conservation Research Center, Watkinsville, Ga.; Water Research Center, Sidney, Mont., and High Plains Grasslands Research Station, Cheyenne, Wyo.

U.S. Plant, Soil, and Nutrition Laboratory--This laboratory is one of the few in the world where scientists of different

disciplines are grouped together to conduct research on the geochemical and chemical processes involved in the cycling of nutritionally important substances in rocks, soils, plants, and animals. The research program includes factors controlling the distribution and availability of nutrients and the structure, synthesis, metabolism, and role of biologically important substances in the growth and development of plants, animals, and humans. The laboratory is located in Ithaca, N.Y.

Water Management Laboratories--These laboratories are located within the physiographic region where major problems of water management and associated soil problems exist. Each laboratory has a group of multidisciplinary scientists--soil scientists, plant physiologists, and engineers--who work together on basic relationships and conduct field experiments under regional climatic conditions.

Research with major crops grown in the area is conducted to develop improved water management technology for increasing water-use efficiency and minimizing soil and crop damage caused by salinity. Facilities are located at the Water Management Research Laboratory, Fresno, Calif.; U.S. Salinity Laboratory, Riverside, Calif.; U.S. Water Conservation Laboratory, Phoenix, Ariz.; Irrigation and Soil-Plant-Water Relations Unit, Fort Collins, Colo.; and Irrigation and Soil-Plant-Water Relations Unit, Grand Junction, Colo.

Watershed Research Centers--These centers, which are located in major climatological zones, consist of unique and intensively instrumented experimental facilities for evaluating the effects of crop and range activities on the environment and the effects of urbanization and mining on agriculture. Multidisciplinary teams of scientists and engineers use these research watersheds to assess the effects of land use and land treatment on water yield, flooding control, soil conservation, channel stabilization, and water quality for key physiographic regions. The research program includes fundamental studies on the movement of water, sediments, and agricultural chemicals. A major objective is the development and evaluation of improved land management and conservation technologies for use by action and regulatory agencies. Federal agencies benefiting directly from the research include the USDA Soil Conservation Service; U.S. Department of the Interior, Bureau of Mines and Bureau of Land Management; U.S. Army Corps of Engineers; and U.S. Environmental Protection Agency. Facilities are located at Southern Plains Watershed and Water Quality Laboratory, Durant, Okla.; North Appalachian Experimental Watershed, Coshocton, Ohio; USDA Sedimentation Laboratory, Oxford, Miss.; Grassland, Soil, and Water Research Laboratory, Temple, Tex.; Southwest Rangeland Watershed Research Center, Tucson, Ariz.; Northwest Watershed Research Center, Boise, Idaho; Southern Plains Watershed and Water Quality Laboratory, Chickasha, Okla.; Southeast Watershed Research Laboratory, Tifton, Ga.; Northeast Watershed Research Laboratory, University Park, Pa.; Watershed Research Unit, Columbia, Mo.; and Watershed Research Unit, Council Bluffs, Iowa.

APPENDIX A:
PRINCIPAL STATUTES

PRINCIPAL STATUTES RELATING TO AGRICULTURAL RESEARCH SERVICE ACTIVITIES

Subject or Popular Title	Public Law No.	Approval Date	Purpose
Organic Act of 1862	None	5/15/1862	In addition to establishing the Department of Agriculture, charges the Commissioner of Agriculture with the duty "...To acquire and preserve in his Department all information concerning agriculture which he can obtain by means of books and correspondence, and by practical and scientific experiments,..." This Act initially authorized the Department of Agriculture to perform a research function in relation to agricultural matters. (12 Stat. 387) (7 U.S.C. 2201, 2204)
Domestic Animals and Poultry	---	5/29/84	Establishes Bureau of Animal Industry to investigate and report on the condition of domestic animals and live poultry in the United States and on the causes and means of preventing diseases among them. (23 Stat. 31) (7 U.S.C. 391)
Dairy Industry	68-156	5/29/1924	Authorizes investigations of the dairy industry and dissemination of information for promotion of the dairy industry. (43 Stat. 243) (7 U.S.C. 402)
Dairy and Livestock Industry	69-490	7/3/26	Authorizes Secretary to establish a dairying and livestock experiment station at Mandan, North Dakota, for investigations and experiments in the dairy and livestock industries and for problems pertaining to establishment and development thereof. (44 Stat. 840) (7 U.S.C. 421)
Arboretum	69-799	5/4/27	Authorizes Secretary to establish a national arboretum for purposes of research and education concerning tree and plant life. (44 Stat. 1422) (20 U.S.C. 191-194)

Subject or Popular Title	Public Law No.	Approval Date	Purpose
Cotton	---	4/12/28	Authorizes Secretaries of Agriculture and Commerce to engage in technical and scientific research on American-grown cotton and its byproducts. (45 Stat. 426) (7 U.S.C. 423)
Dairy Industry	---	5/29/28	Authorizes Secretary to establish a dairy station at Lewisburg, Tennessee, for investigations, experiments, and demonstrations in the dairy industry and the problems pertaining to the dairy industry in the South. (45 Stat. 981) (7 U.S.C. 422)
Cotton Ginning	71-160	4/19/30	Authorizes Secretary to investigate ginning of cotton, to establish and maintain experimental ginning plants and laboratories, and to make tests and technical and scientific studies with respect thereto. (46 Stat. 24) (7 U.S.C. 424)
Soil Conservation Act	74-46	4/27/35	Authorizes Secretary to conduct surveys, investigations, and research relating to the character of soil erosion and the preventive measures needed and relating to economic use and conservation of land. (49 Stat. 163) (16 U.S.C. 590a)
Regional Research Laboratories	75-430	2/16/38	Authorizes Secretary to establish four laboratories, one in each major farm producing area, to conduct research into and to develop new scientific, chemical, and technical uses and new and extended markets for farm commodities and products and byproducts thereof. (52 Stat. 37) (7 U.S.C. 1292)
Poultry Improvement	78-425	9/21/44	Authorizes Secretary to cooperate with State authorities in the administration of regulations for the improvement of poultry, poultry products, and hatcheries. (58 Stat. 734) (7 U.S.C. 429)

Subject or Popular Title	Public Law No.	Approval Date	Purpose
Substitutes for Strategic Materials	79-520	7/23/46	Authorizes Secretary to make scientific, technologic, and economic investigations of the feasibility of developing domestic sources of supplies of any agricultural material or of using agricultural commodities for the manufacture of any material determined to be strategic and critical. (60 Stat. 599) (50 U.S.C. 98f)
Research and Marketing Act of 1946	79-733	8/14/46	Authorizes Secretary to conduct research into basic laws and principles relating to agriculture; to improve and facilitate the marketing and distribution of agricultural and the development of new and improved methods for the production, marketing, distribution, processing, and utilization of plant and animal commodities at all stages from the original producer to the ultimate consumer; to conduct research in the areas of human nutrition, development of new use and markets for agricultural commodities and agricultural resources (manpower, soil, plants, animals, and equipment); to conduct research relating to conservation, development, and the use of land, forest, and water resources; and authorizes the Secretary to enter into contracts with public or private organizations or individuals when in his judgment the research can be carried out more effectively, more rapidly, or at lower cost than if performed by Department personnel. (60 Stat. 1082) (7 U.S.C. 427, 1621)

Subject or Popular Title	Public Law No.	Approval Date	Purpose
Horse Breeding	80-494	4/21/48	Authorizes Secretary, in connection with transfer of any remount service to the Department, to improve breeding of horses suited to the United States. (62 Stat. 197) (7 U.S.C. 437)
Foot and Mouth Research	80-496	4/28/48	Authorizes Secretary to establish research laboratories and conduct and contract for research of foot-and-mouth and other animal diseases. (62 Stat. 198) (21 U.S.C. 113a)
Cattle Grubs	80-651	6/16/48	Authorizes Secretary to increase and intensify research and investigations into problems and methods relating to the eradication of cattle grubs. (62 Stat. 458) (21 U.S.C. 114c)
Commodity Credit Corporation Charter Act	80-806	6/29/48	Authorizes research relating to the conservation or disposal of commodities owned or controlled by the corporation in collaboration with research agencies of the Department. (62 Stat. 1070) (7 U.S.C. 612c)
Virgin Islands	82-228	10/29/51	Authorizes Secretary to establish, in the Virgin Islands of the United States, an agricultural research and extension service program. (65 Stat. 661) (48 U.S.C. 1409)
Agricultural Trade Development and Assistance Act	83-480	7/10/54	Authorizes the sale of agricultural commodities to friendly countries; authorizes the use of foreign currencies accruing from such sales for a variety of research activities. Sec. 104(b)(1) provides that foreign currency receipts may be used to develop new markets for U.S. agricultural commodities. Sec. 104 (b)(2) provides that foreign

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			currency receipts may be used to collect and disseminate scientific and technologic information, conduct research, and support scientific activities overseas. This Act includes programs of scientific cooperation between the United States and other countries, such as coordinated research against diseases common to all mankind or unique to individual regions. Sec. 104(b)(3) also authorizes support for programs of medical and scientific research, cultural and educational development, family planning, health, nutrition, and sanitation. (68 Stat. 454) (7 U.S.C. 1691)
Research Grants-Basic	85-934	9/6/58	Authorizes Federal agencies to make grants for basic scientific research at nonprofit institutions of higher education or at nonprofit organizations whose primary purpose is the conduct of scientific research. (72 Stat. 1793) (42 U.S.C. 1891)
Humane Slaughter Research	85-765	9/27/58	Authorizes Secretary to conduct, assist, and foster research, investigations, and experimentation to determine and to develop methods of slaughter, and methods for handling livestock in connection with slaughter, that will be humane. (72 Stat. 863) (7 U.S.C. 1904)
Housing Act of 1949	87-70	8/30/61	Authorizes Secretary to conduct research on the adequacy of existing farm housing and on current and prospective needs for farm housing, interrelation of farm housing problems with housing problems of urban and suburban areas, and other matters bearing on the provision of adequate farm housing. (75 Stat. 188) (42 U.S.C. 1476b)

Subject or Popular Title	Public Law No.	Approval Date	Purpose
Cooperative Research Projects	88-250	12/30/63	Authorizes ARS Administrator to enter into agreements and receive funds from State or other political subdivisions, organizations, or individuals. (77 Stat. 820) (7 U.S.C. 450a)
Agricultural Act of 1964	88-297	4/11/64	Authorizes Secretary to conduct a special cotton research program designed to reduce the cost of producing upland cotton in the United States (78 Stat. 174) (7 U.S.C. 14)
Research Grants-Special	89-106	8/4/65	Authorizes Secretary to make grants to State agricultural experiment stations, colleges, universities, and other research institutions and organizations and to Federal and private organizations and individuals for basic and applied research to further the programs of the Department. (79 Stat. 431) (7 U.S.C. 4501)
Tropical Research	89-808	11/11/66	Authorizes Secretary to conduct research in tropical and subtropical agriculture for the improvement and development of tropical and subtropical food products for dissemination and cultivation in friendly countries. (80 Stat. 1537) (7 U.S.C. 1736 (a)(4)
Federal Water Pollution Control Act	92-500	10/18/72	Authorizes Administrator of EPA, in cooperation with other Federal agencies, to develop comprehensive programs for water pollution control, and, in establishing National Programs therefor, to cooperate with other Federal agencies in conducting research, investigations, training, and information programs including, among other things, a comprehensive study and research program for preventing, reducing, and eliminating pollution from agriculture.

57-279 O - 87 - 34

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			Authorizes the Administrator of EPA, in consultation with the Secretary of Agriculture, to make grants for research and dissemination of information with respect to methods of preventing and of eliminating pollution from agriculture. (86 Stat. 816) (33 U.S.C. 1151)
Agriculture and Consumer Protection Act of 1973 (Farm Bill)	93-86 (Sec 809)	8/10/73	Authorizes and directs Secretary to carry out a comprehensive study and investigation to determine the reasons for the extensive loss of livestock sustained each year through their subjection to injury and disease during transport in interstate commerce for commercial purposes. Also authorizes and directs Secretary to conduct, in connection with such study and investigation, an intensive research program for the purpose of developing measures that can be taken to reduce materially the number of animals lost through injury and disease during their transport for commercial purposes. (This authority terminated after 4 years.) (87 Stat. 221) (7 U.S.C. 1305)
Agriculture and Consumer Protection Act of 1973 (Farm Bill)	93-86 (Sec 611)	8/10/73	Authorizes and directs Secretary to carry out programs to destroy and eliminate cotton boll weevils in infested areas of the United States and to carry out similar programs with respect to pink bollworms or any other major cotton insect if he determines that methods and systems have been developed to the point that success in eradication of such insects is assured. The Secretary shall carry out, through the Commodity Credit Corporation, the eradication programs authorized by this subsection. In carrying out insect eradication projects, he shall utilize the technical and related

Subject Popular Title	Public Law No.	Approval Date	Purpose
			services of appropriate Federal, State, and private agencies and cotton organizations. (87 Stat. 235) (7 U.S.C. 1305)
Agriculture and Consumer Protection Act of 1973 (Farm Bill)	93-86 (Sec 810)	8/10/73	Authorizes and directs Secretary to carry out regional and national research programs to reduce fertilizer and herbicide usage in excess of production needs, to develop wheat and feed grain varieties more susceptible to complete fertilizer utilization, to improve the resistance of wheat and feed grain plants to disease, and to enhance conservation and environmental qualities. (87 Stat. 238) (7 U.S.C. 1305)
National Arboretum	94-129	11/13/75	Authorizes Secretary to accept, receive, hold, utilize, and administer--on behalf of the United States--gift bequests or devises of real and personal property made for the benefit of the National Arboretum. (89 Stat. 683) (20 U.S.C. 195)
International Development and Food Assistance	94-161 Title II Sec 214	12/20/75	Transfers Farmer-to-Farmer Program from the Secretary of Agriculture to the President. (89 Stat. 849) (22 U.S.C. 2151)
Surface Mining Control and Reclamation Act of 1977	95-87	8/3/77	Sets environmental-protection performance standards to be met at all major surface mining operations for coal; provides for joint responsibility and enforcement by the States and the Federal Government; establishes a self-supporting Abandoned Mine Reclamation Fund to restore land ravaged by uncontrolled mining operations in the past; protects certain land regarded as unsuitable for surface mining; establishes mining and mineral resource institutes and provides

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			funds for coal research laboratories and graduate fellowships; and provides for a transfer of funds to USDA for technical and financial assistance to landowners entering into long-term agreements for reclamation purposes. (91 Stat. 445) (30 U.S.C. 120)
Food and Agriculture Act of 1977 (Farm Bill)	95-113 (Title 14)	9/29/77	Assigns USDA the lead agency role with respect to national food and agricultural science. It also provides for coordination, expanded efforts in priority areas, and widening participation in research and education beyond the USDA and Land Grant University system. The law provides for expansion of USDA involvement in agricultural solar energy research, development, and demonstration, and grants USDA authority to be a full participant in nutrition research and education and in internationally related food and agricultural research and education. Establishes several coordinating and policy committees within USDA (91 Stat. 981) (7 U.S.C. 3101)
Soil and Water Resources Conservation Act of 1977	95-192	11/18/77	Provides that the Secretary shall appraise, on a continuing basis, the soil, water, and related resources of the Nation; develop and periodically update a program for furthering the conservation, protection, and enhancement of the soil, water, and related resources of the Nation; and provides that the President shall transmit periodically, to the Congress, the appraisal of the program as required by this Act. (91 Stat. 1407) (16 U.S.C. 2001)
Clean Water Act of 1977	95-217	12/27/77	Exempts irrigation return flows from the permit system requirements of section 402 of the Federal Water Pollution Control Act of 1972 and

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			defines them as nonpoint sources to be considered in areawide waste treatment management plans. (91 Stat. 1566) (33 U.S.C. 1251)
Surface Mining Control and Reclamation Act of 1977, Amendments	95-343	8/11/78	Authorizes funds for FY 1979 and 1980 for surface mining control and reclamation. (92 Stat. 473) (30 U.S.C. 1302)
Roman L. Hruska Meat Animal Research Center, Nebraska Designation	95-436	10/10/78	Designates the Meat Animal Research Center, located near Clay Center, Nebraska, as the "Roman L. Hruska Meat Animal Research Center." (92 Stat. 1054)
Public Lands Relinquishment of Jurisdiction	95-441	10/10/78	Authorizes Secretary to relinquish exclusive legislative jurisdiction over lands or interests under his control. (92 Stat. 1064) (7 U.S.C. 2268)
Gifts and Property Acceptance and Administration by Secretary of Agriculture	95-442	10/10/78	Authorizes the Secretary to accept and administer, on behalf of the United States, gifts or devises of real and personal property for the benefit of the Department of Agriculture or of any of its programs. (92 Stat. 1065) (7 U.S.C. 2269)
Humane Methods of Slaughter Act of 1978	95-445	10/10/78	Prohibits inhumane slaughtering of livestock within the United States and the importation of any meat or meat products unless such livestock are slaughtered in a humane manner. (92 Stat. 1069) (21 U.S.C. 601)
Carl Hayden Bee Research Center Designation	95-446	10/10/78	Designates the United States Department of Agriculture's Bee Research Laboratory in Tucson, Arizona, as the "Carl Hayden Bee Research Center." (92 Stat. 1071)

Subject or Popular Title	Public Law No.	Approval Date	Purpose
W. R. "Bob" Poage Pecan Field Station, Texas Designation	95-451	10/11/78	Designates the U.S. Department of Agriculture's Pecan Field Station in Brownwood, Texas, as the "W. R. 'Bob' Poage Pecan Field Station." (92 Stat. 1100)
Water Research and Development Act of 1978	95-467	10/17/78	Promotes a more adequate and responsive national program of water research and development. (92 Stat. 1305) (42 U.S.C. 7801)
Food and Agriculture Act of 1977, Amendment (Farm Bill)	95-547	10/28/78	Amends section 1445(b) of the Food and Agriculture Act of 1977 to modify the formula for distribution of funds authorized thereunder for agricultural research. (92 Stat. 2063) (7 U.S.C. 3222)
Native Latex Commercialization and Economic Development Act 1978	95-592	11/4/78	Authorizes the Secretaries of Agriculture and Commerce to coordinate basic and applied research, technology development, and technology transfer leading to effective and economical methods for large-scale culturing of plantations and to the extraction of latex. (92 Stat. 2529) (7 U.S.C. 178)
Energy Security Act	96-294	6/30/80	Authorizes funds to establish the production of synthetic fuels, gasohol, solar energy, renewable resources, and geothermal energy; to establish an energy conservation program and energy supply targets; and to extend the Defense Production Act until September 30, 1986. Title II establishes a comprehensive biomass and alcohol fuels program and urban waste program. Part A of this title contains new programs for USDA, including forestry. Title VII calls for two research programs: (1) Acid Precipitation and (2) Carbon Dioxide. The acid precipitation study sets up an

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			interagency task force jointly chaired by National Oceanic and Atmospheric Administration, EPA, and USDA. The 10-year study includes identifying sources contributing to, monitoring levels of, and formulating recommendations to alleviate acid precipitation. (94 Stat. 611) (42 U.S.C. 8701)
Rural Development Policy Act of 1980 Amendment	96-355	9/24/80	Amends Sec. 2 of the Rural Development Act of 1972 (Public Law 92-419; 86 Stat. 657) by adding a new section, Section 607, which directs the Secretary to assume a leadership role in coordinating a nationwide rural development program by developing a rural development policy, preparing and implementing a rural development program policy, preparing and implementing a rural development strategy and updating it annually, and maximizing coordination of Federal programs affecting rural areas. Reauthorized Title V until 1981. (94 Stat. 1171) (7 U.S.C. 2201)
National Aquaculture Act of 1980	96-362	9/26/80	Provides for a strong national policy statement promoting aquaculture in the United States and calls for the development of a National Plan for Aquaculture, thus encouraging activities and programs in both the public and private sectors of the economy. The bill further provides for studies to investigate the need for financial programs and to examine how we reduce undue regulatory constraints that may face the aquaculture industry. (94 Stat. 1198) (16 U.S.C. 2801)
Animal Cancer Research Act	96-469	10/17/80	Authorizes the Secretary to conduct a program of basic research on cancer in animals and birds at appropriate

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			facilities within USDA, or by grants to other qualified research facilities, and requires consultation and coordination of animal cancer research between the Department of Agriculture and the National Institutes of Health until the end of Fiscal Year 1986. (94 Stat. 2235) (7 U.S.C. 3901)
Stevenson-Wydler Technology Innovation Act of 1980	96-480	10/21/80	Establishes a national policy on the transfer, to local and State governments and to the private sector, of federally funded technology emanating from agencies and laboratories. The law requires each Department to establish, in selected Federal laboratories, an Office of Research and Technology Applications and to mobilize all Federal laboratories in support of technology transfer. (94 Stat. 2311) (15 U.S.C. 3701)
Robert Wentworth Harned Laboratory Designation	97-77	11/13/81	Redesignates the U.S. Department of Agriculture Boll Weevil Research Laboratory, located at Starkville, Mississippi, as the "Robert Wentworth Harned Laboratory." (95 Stat. 1069) (7 U.S.C. 1446)
Agriculture and Food Act of 1981 (Farm Bill)	97-98 (Title XIV)	12/22/81	Extends by four years the Congressional authorization to provide adequate support to funding for research, extension, and teaching aimed at continued gains in the productivity of the agricultural sector. The legislation also provides for strengthening the research and extension partnership between the U.S. Department of Agriculture and the Nation's land-grant colleges and universities. It also expands the scope of activities to include aquaculture, rangeland management, and a Dairy Goat Research Center. Other provisions include authorization for a research extension program

Subject or Popular Title	Public Law No.	Approval Date	Purpose
			concentrating on rural development and small farm problems; establishment of a Soybean Research Advisory Institute within USDA; a requirement that the Secretary of Agriculture include, in a regular annual report due January 1, 1984, a long-term needs assessment for food, fiber, and forest products; a directive to the Secretaries of Agriculture and Health and Human Services to report within 180 days on plans for a human nutrition research and information management system; an authorization for a building fund of $10 million per year for the next five years for the 1890 institutions; a requirement that the Hatch Act be funded at a level at least equal to 25 percent of the funding level for all agricultural research; and a requirement that an Assistant Secretary of Agriculture be appointed to administer the provisions relating to the research, extension, and teaching activities of the Department. (95 Stat. 1213) (7 U.S.C. 1281)

APPENDIX B:
AGRICULTURAL
RESEARCH SERVICE
OFFICES

LOCATION OF HEADQUARTERS, REGIONAL AND AREA OFFICES, AND MAJOR RESEARCH CENTERS

Office of the Administrator, Washington, D.C.
National Program Staff, Beltsville, Md.

NORTHEASTERN REGION — Regional headquarters: Beltsville, Md.

Area Offices

North Atlantic Area, Ithaca, N.Y. (includes N.Y., Pa., N.J., Vt., N.H., Maine, Conn., Mass., R.I., Md., Del., and W. Va.)
Beltsville Agricultural Research Center, Beltsville, Md.
Plum Island Animal Disease Center, Orient Point, N.Y.
Eastern Regional Research Center, Wyndmoor, Pa.
Beltsville Human Nutrition Research Center, Beltsville, Md.
Human Nutrition Research Center on Aging, Boston, Mass.

NORTH CENTRAL REGION — Regional headquarters: Peoria, Ill.

Area Offices

Illinois-Indiana-Michigan-Ohio Area, Lafayette, Ind.
Dakotas-Minnesota-Wisconsin Area, St. Paul, Minn.
Mid-Great Plains Area, Columbia, Mo. (includes Iowa, Mo., Nebr., and Kans.)
Northern Regional Research Center, Peoria, Ill.
National Animal Disease Center, Ames, Iowa
Grand Forks Human Nutrition Research Center, Grand Forks, N. Dak.

SOUTHERN REGION — Regional headquarters: New Orleans, La.

Area Offices

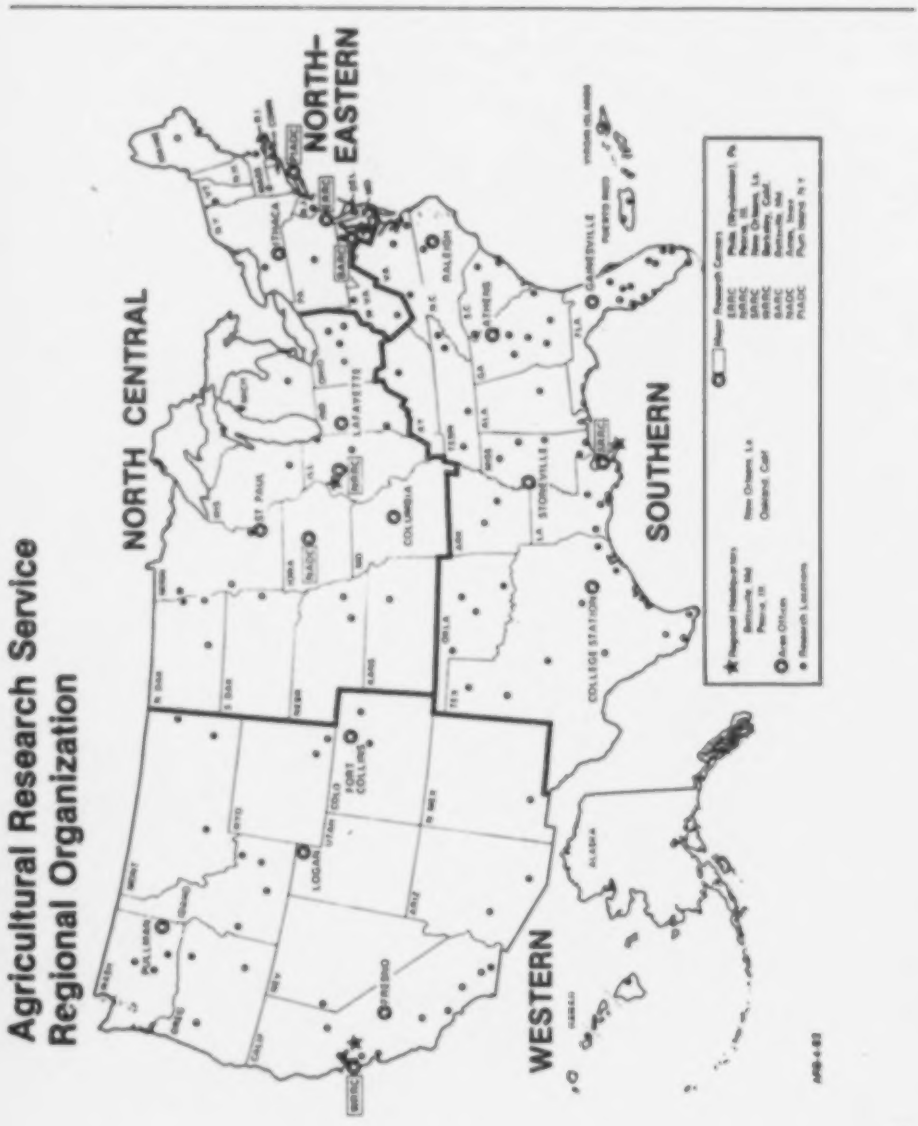
Florida-Antilles Area, Gainesville, Fla. (includes Fla., P.R., and V.I.)
Southeast Area, Athens, Ga. (includes Ga. and Ala.)
Delta States Area, Stoneville, Miss. (includes Miss., La., and Ark.)
Mid-Atlantic Area, Raleigh N.C. (includes N.C., Tenn., Ky., Va., and S.C.)
Oklahoma-Texas, College Station, Tex.
Southern Regional Research Center, New Orleans, La.
Children's Nutrition Research Center, Houston, Tex.

WESTERN REGION Regional headquarters: Oakland, Calif.

Area Offices

California-Hawaii Area, Fresno, Calif.
Rocky Mountain Area, Ft. Collins, Colo. (includes Colo., Wyo., Mont., and Alaska)
Arid Southwest Area, Logan, Utah (includes N. Mex., Ariz., Nev., and Utah)
Pacific Northwest Area, Pullman, Wash. (includes Oreg., Wash., and Idaho)
Western Region Research Center, Albany, Calif.
Western Human Nutrition Research Center, San Francisco, Calif.

APPENDIX C:
MAP SHOWING MAJOR
ARS LOCATIONS



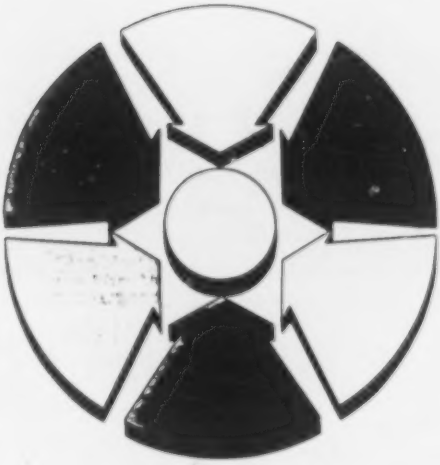
United States
Department of
Agriculture

Agricultural
Research Service

Miscellaneous
Publication
Number 1429

January 1983

Agricultural Research Service Program Plan



Goal:
Through fundamental and applied research, ARS seeks to provide the means for solving the technical food and agricultural problems of broad scope and high national priority as required to ensure, perpetually, an adequate supply of high-quality food and fiber for the American people and for export.

Objectives:
Develop the means for—

1. Managing and conserving the Nation's soil and water resources for a stable and productive agriculture;
2. Maintaining and increasing the productivity and quality of crop plants;
3. Increasing the productivity of animals and the quality of animal products;
4. Achieving maximum use of agricultural products for domestic markets and export;
5. Promoting optimum human health and well-being through improved nutrition and family resource management; and
6. Integrating scientific knowledge of agricultural production, processing, and marketing into systems that optimize resource management and facilitate transfer of technology to users.

Foreword

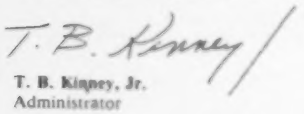
The Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA) must respond to the needs of our complex agricultural enterprise. Agriculture accounts for about 20 percent of the Nation's business volume and employment and, in 1981, accounted for about 19 percent of its exports, but it does not always provide farmers with a reasonable return from their investments of land, labor, and capital. Our agricultural enterprise is committed to supplying the needs of consumers, at home and abroad, with wholesome, nutritious food and other farm products at affordable prices. In continuing to meet that commitment, U.S. agriculture faces an array of major challenges, which include conserving our natural resources, improving the efficiency of production, and increasing the use of farm products.

I asked ARS scientists and the National Program Staff (NPS) to devise a strategy that would provide, through research, the means by which U.S. agriculture could meet those challenges. In response, they developed this document, the ARS Program Plan. The Plan records the best thinking, of approximately 500 ARS scientists and the members of the NPS, on how ARS can meet agriculture's short- and long-term needs most effectively and efficiently. As my part in strategic planning, I revised the management philosophy of ARS and formulated the policies for the Implementation Strategy. The policies establish the principles and standards that will guide the Agency in following the Program Plan. They also provide guidelines for collaboration and teamwork among ARS employees in line and staff positions. In accordance with those policies, I will operate the ARS as a managed activity, coordinated by plan.

The Program Plan provides for close coordination with other research organizations in and out of USDA, the action agencies in USDA, and other organizations that use our research findings. I want to emphasize the special working relationships between ARS and the State Agricultural Experiment Stations. Cooperative research programs must continue their valuable contributions to the development of science for agriculture.

The Program Plan includes programs for meeting future, as well as present, needs of U.S. agriculture. On the basis of recommendations by the scientists and the NPS, and guided by the policies, a Six-Year Implementation Plan is being prepared. In it we identify the programs of highest priority that ARS will support first. We are developing the projected resource allocations for those high-priority research programs. That information will guide decisionmaking by management at all levels in ARS. Programs will be evaluated systematically to identify areas of significant progress, major constraints to further progress, emerging research problems and opportunities, and research that can be discontinued. Such evaluations will guide me in managing the physical, financial, and human resources of ARS.

We will measure the success of our strategic planning by our progress in the ARS mission of producing new knowledge and technologies for the Nation's food and agricultural enterprise. Evidence of our progress will be outstanding, innovative research that meets the needs of U.S. agriculture and that, in turn, will help sustain and improve the well-being of our people for generations to come.



T. B. Kinney, Jr.
Administrator

Contents

	Page
Summary	1
Introduction	3
Challenges to Agriculture	3
The Challenge to Agricultural Research	8
The ARS Program Plan	10
The ARS Program Strategy	15
Overall Research Strategies	15
Objective 1. Develop the Means for Managing and Conserving the Nation's Soil and Water Resources for a Stable and Productive Agriculture.	17
Objective 2. Develop the Means for Maintaining and Increasing the Productivity and Quality of Crop Plants.	25
Objective 3. Develop the Means for Increasing the Productivity of Animals and the Quality of Animal Products.	35
Objective 4. Develop the Means for Achieving Maximum Use of Agricultural Products for Domestic Markets and Export.	43
Objective 5. Develop the Means for Promoting Optimum Human Health and Well-Being Through Improved Nutrition and Family Resource Management.	51
Objective 6. Develop the Means for Integrating Scientific Knowledge of Agricultural Production, Processing, and Marketing Into Systems That Optimize Resource Management and Facilitate Transfer of Technology to Users.	57
Implementation Strategy—Policies	63
Appendix	71
The Planning Process	71
Acknowledgments	72

Issued January 1983

The Agricultural Research Service Program Plan

Summary

The Agricultural Research Service Program Plan represents the best thinking of about 500 scientists and members of the National Program Staff (NPS), Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), who participated in the strategic planning process. The Plan reflects the concern of the scientists about supplies of high-quality food and other farm products at affordable prices for U.S. citizens and for export, about the economic welfare of the U.S. agricultural enterprise, and about conserving the Nation's natural resources. Members of the NPS organized the ideas and recommendations of scientists into this Program Plan.

The goal of the Plan is to ensure, perpetually, an adequate supply of high-quality food and fiber for the American people and for export. The six objectives that will lead to the ARS goal deal with conserving and managing natural resources, increasing the productivity of plant crops and of livestock, marketing farm products efficiently, improving the nutrition of people, and developing agricultural systems. Each objective is presented in one of the six main sections of the Program Strategy. In each section, background information, needs that justify the research proposed, and the potential benefits of the research are reported. Research approaches and specific elements for each approach are listed and discussed. In the sections for the objectives, ARS scientists propose using the most advanced physical, chemical, and biological technologies to meet the short- and long-term needs of U.S. agriculture and, ultimately, to meet the needs of people worldwide. Those proposals provide a wealth of ideas for sparking new ARS programs well into the next century.

For the ARS Implementation Strategy of strategic planning, the Administrator established the six major policies that define his courses of action for operating ARS as a federally funded and managed agency. He will operate ARS as a managed activity coordinated by plan. The Deputy Administrator and the NPS are responsible for and are now developing the Six-Year Implementation Plan. The policies provide for the major functions needed for achieving the six objectives of the Program Strategy, and they assign the responsibility for establishing priorities in the Six-Year Implementation Plan. Regional administrators are responsible for operational plans, and the Administrator has overall responsibility for coordination and execution of the programs. The Deputy Administrator is responsible for systematic evaluation of programs. The ARS is continuing its research in, and its exchange of technology with, foreign countries. The policies were designed to ensure that ARS, the primary research agency of USDA, functions effectively and efficiently.

By policy, the ARS Program Plan provides an optimum balance between the fundamental research needed for long-term solutions to agricultural problems and the applied research needed by action agencies in the Department and by other users of research to carry out their responsibilities. The Plan stresses the innovation and creativity that characterize the ARS research program. By their strategic planning, ARS scientists ensure that their Agency can mobilize its talent and facilities to develop the science needed to meet present and future challenges to U.S. agriculture.

Research has revolutionized American agriculture. No aspect has gone untouched, from the planting of superior seeds to the ultimate consumption of wholesome and nutritious food. Farmers and agribusinesses apply research findings in the use of natural resources and produce an abundance of food and fiber unmatched in the history of mankind. Agricultural productivity, which has increased a phenomenal 240 percent in the past 50 years, has freed millions of people for other kinds of work and accounted for much of the industrial growth in the United States. Today, about 22 million people work in some phase of agricultural production, processing, and distribution and make agriculture and its related industries our largest business. Americans spend a smaller proportion of their income on food—about 16 percent—than do people in any other country.

Challenges to Agriculture

Despite the past performance record of American agriculture and the current surpluses of some crops, many studies and assessments question its ability to meet future demands for food and other agricultural products. The main challenges are as follows:

- The United States has become the residual supplier of agricultural commodities for a growing world population. In 1981, crops harvested from nearly 40 percent of all U.S. acreage and valued at about $44 billion were destined for foreign markets. World food production must double in the next 40 years to meet projected demands.

- Our base of natural resources has declined in quantity and quality because groundwater supplies have diminished, farmlands and irrigation water have been lost to other uses, and excessive erosion of top soil continues from about a third of our farmlands. Additional land and water supplies can be developed, but their costs will be higher and their productivity lower than for those now in use.

• The productivity of key components of agriculture is beginning to peak or flatten out. Average farm yields of crops such as cotton, rice, sugarcane, and dry edible beans have not increased in many years, and yields of other crops may also be peaking. The productivity of farmers' inputs actually declined 7 percent during the 1970's. That trend is continuing into the 1980's; farmers' costs for inputs are increasing and the productivity of the inputs is generally decreasing.

• We face an increasing number of new constraints that include high costs of petroleum and natural gas and of products, such as fertilizer, that are derived from them; increasingly erratic weather patterns in the past decade; only fair to poor condition of about 60 percent of our rangelands; increasing regulation of agricultural chemicals and processes; and many actual or potential environmental constraints, such as air pollution and declining water quality.

• Improving the economic health of agriculture and of its independent entrepreneurs is a major challenge. To adopt new technologies and to meet the anticipated needs of future generations, agricultural business must be economically strong.

All the energy that is essential for the growth of plants—and, therefore, for the production of food and fiber—comes from the sun. Green plant tissues capture the sun's energy in chlorophyll and, by photosynthesis, make the chemical compounds that we eventually use for food, clothing, shelter, and other purposes. However, plants capture only a small fraction of the sunlight available on earth. Animals convert plant materials into meat, milk, and other foods. However, humans eat, as primary foods, only a small fraction of the plant materials produced; most plants are grown as food for animals. To meet projected needs of the world's growing population and to enhance its standard of living, scientists must optimize photosynthesis by plants and the conversion of plants to animal products.

Because the land area suitable for growing crops is limited, food and fiber production with existing technologies and management practices will also be limited. Are we approaching that limit? Some experts argue that we may already have exceeded the long-term, sustainable productive capacity of the earth. Others argue that we have barely scratched the surface of productive capacity.

Scientists who question the sustainability of current agricultural capacity point out its heavy dependence on energy from fossil fuels that store the energy captured through photosynthesis by green plants that lived millions of years ago. Our food production, therefore, depends not only upon the energy available from the sun daily, but also upon prehistoric sunlight stored in fossil fuels. As we deplete those nonrenewable energy reserves, the potential for agricultural production from them will be lost or become increasingly more expensive.

About half the original topsoil has been removed from U.S. farmlands by erosion. About one-third of the ground water used for irrigation in the 17 Western States is being pumped from aquifers faster than they can be recharged. Other causes for concern include loss of farmlands and irrigation water to other uses, depletion of phosphate

reserves, salinization of land and water, loss of potentially valuable germplasm, and adverse effects of pollutants such as acid rain.

The yields of some crops are not increasing. Most of the people in the world eat rice and wear cotton clothes. Despite high inputs of fossil fuels and technology, neither rice nor cotton yields have increased appreciably in the United States since 1965. Their rates of yield increase are stalled (fig. 1). Although future demands for cotton products and rice are not clear, most estimates indicate that demands will increase. How then will the yields and production efficiency of cotton and rice be increased?

Scientists and others who argue that we have much unused productive capacity make several claims. They point out that the primary goal of past research was to increase production per unit of land and of labor, the two most costly production factors. Thus, they argue, the past record may not be a valid basis for accurately predicting the ability of scientists to improve the yields of crops and the efficiency of resource use in the future. Those people claim that because farmers' average crop yields are only a third or less of maximum experimental crop yields, considerable biological potential remains to be exploited. They also claim that, so far, we have always found ways to increase productivity. A novel claim is that the complex of modern technologies provides a new resource—technology itself—that generates "science power." Unlike natural resources, technology is manmade and its proponents think that science power could increase agricultural productivity indefinitely, as depicted for the last 50 years in figure 2.

The concept of science power piques our imaginations and heightens our expectations. For example, dare we expect that, when conventional techniques have failed, scientists could use science power to produce plants that capture extra sunlight or to produce cereal crops that fix nitrogen directly from the air? Dare we expect that they will use science power to slow the drain on our natural resources or to harness new sources of energy as substitutes for fossil fuels? We can imagine that those feats—and others—are possible. If we expect to realize such feats, however, we must gain the fundamental knowledge and experience necessary to address the constraints that limit agricultural productivity today. We cannot predict accurately the shape that the productivity growth curve will assume by the year 2000. Nor can we predict that science power will continue indefinitely to support growth at the rate indicated by extrapolation of figure 2.

Of the growth in overall productivity attributed to science power, how much accrued from innovation, without extra drain on our natural resources? The use of improved crop varieties does increase yield, but often the increase is at least partially due to their use of extra nitrogen fertilizer. Examples are the short, stiff-straw rice and wheat cultivars that resist lodging even when highly fertilized. The data indicate that those and other high-yielding crops do not use fertilizer more efficiently than do other crops, they just use more of it. Some crop breeders think that we have largely exploited the advantages of the short, stiff-straw characteristic in those crops. Many authors report that past increases in production depend, in fact, upon increased use of fossil fuels, water, chemicals of many kinds, and other resources.

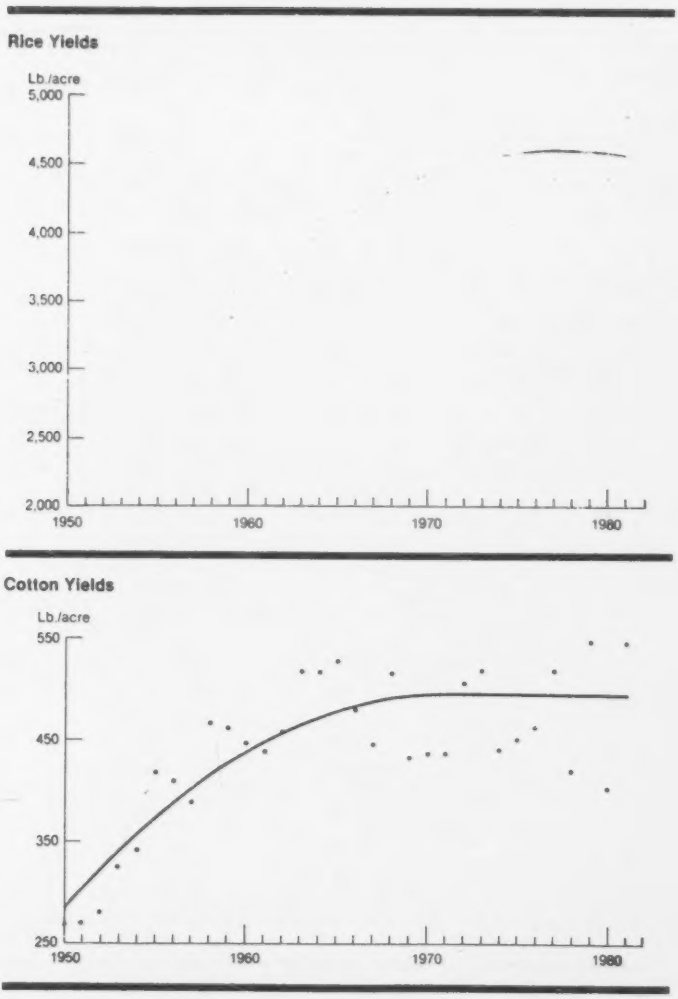


FIGURE 1.—Yield trends for rice and cotton (from Needs Assessment Committee Report, "Future Needs for Agricultural Products and Resources," 1981).

Related to the question of sustaining long-term growth in productivity is the need for year-to-year stability. Because so little food is stored worldwide each year, and because the differences between shortages and surpluses often are less than 10 percent of average production, our ability to feed ourselves and to export food and feed crops is determined to a considerable extent by production in the worst years, rather than by that in average years. Production stability is related more closely to weather than to any other factor, and the erratic weather patterns of the past decade probably are more typical of the norm than are the stable patterns of the 1950's and 1960's. As the world population grows and production potentials are reached, we may not have the crop surpluses of the past to tide us over severe droughts like the one in 1980.

Prediction of the effects of the main challenges to agriculture on supplies and costs of food and feed would be speculative. Most experts seem to agree that the demand for export of large quantities of grains and other farm products will continue. However, our land reserves will be used fully in the next 20 to 30 years, and any further increases in supplies of food, feed, and fiber must come from increased productivity of our natural resources, our crops and livestock, and our marketing systems. Even with low-demand projections, the required rates of productivity translate into dramatic numbers—275 bushels per acre of corn by the year 2000 and 385 bushels per acre by the year 2050. Such yields equal or exceed the highest experimental yields ever produced and are about three times as high as average farm yields (110 bushels of corn per acre in 1981). With

U.S. Agricultural Productivity Growth During the Past 200 Years

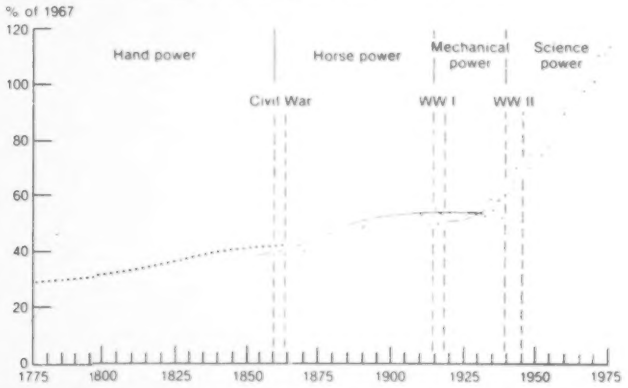


FIGURE 2.—Growth of U.S. agricultural productivity during the past 200 years. (Lu, Yau-Chi, Philip Cline, and Leroy Quance. Prospects for Productivity Growth in U.S. Agriculture. USDA Agricultural Economic Report No. 435, Sept. 1979.)

high-demand projections, the yields required would be higher than the limits imposed by the photosynthetic capacity of today's crops. Production of crops and livestock is only part of the story. Raw agricultural products must be marketed and processed into useful forms. Only through radically improved technology can we develop the marketing systems needed for efficiently handling, storing, and processing such huge quantities of food and fiber.

The success or failure of science as a whole might well be judged by the success or failure of the agricultural sciences during the next few decades. Without adequate scientific knowledge, we have little hope of responding rationally to the risks and uncertainties of an unpredictable future.

The Challenge to Agricultural Research

Many groups fund and perform research and development for agriculture. The major contributors and the percentage of funds from each are shown in figure 3. The private sector provides the major share of the funding, predominantly in the physical sciences and engineering, for developing processes and products that yield a profit in the marketplace. In contrast, public research funds are concentrated in biological sciences and technology, where profits are not so easily captured. Public funds also support a larger proportion of long-term and basic research than do funds provided by industry. Public funds, both State and Federal, are crucial for continued support of higher education in all phases of agriculture where research is an integral and essential part of advanced training in the biological, social, and physical sciences and in engineering. The "other Federal" category includes funds for agencies such as the Forest Service, Economic Research Service, and Cooperative State Research Service in the U.S. Department of Agriculture (USDA), as well as for many agencies outside the Department.

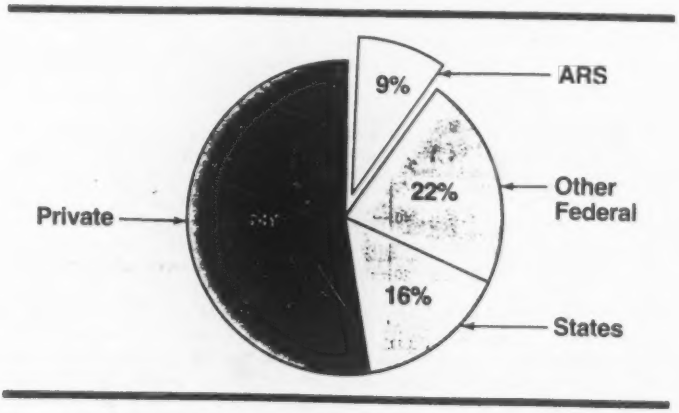


FIGURE 3.—Public and private funds for U.S. food and agricultural research.

The Agricultural Research Service (ARS) is the Department's principal intramural research agency. It has long-standing working relationships with the other research agencies in the Department, the State Agricultural Experiment Stations, and the private research sector. The ARS also works closely with the action agencies in the Department and serves as the research arm for many of them. Interagency programs within the Department are critical in such areas as soil and water conservation, range improvement, control of plant and animal diseases, and food safety.

The mission of the ARS is—

> To plan, develop, and implement research that is designed to produce the new knowledge and technologies required to assure the continuing vitality of the Nation's food and agricultural enterprise. As a Federal research agency, ARS (1) addresses problems that are of legitimate national concern, (2) conducts research that is appropriate for the Federal Government, and (3) exploits the unique capabilities of ARS scientists and the facilities they operate—a combination that forms an integrated and coordinated national resource that is not duplicated by others in the full U.S. agricultural research and development system.

In fulfilling its responsibility for assuring that the Nation has adequate supplies of high-quality food and fiber, the Department supports a wide range of research and educational activities, but it is primarily the ARS that must address the long-range, high-risk problems of national and international concern. The two overriding objectives of the Administration are bolstering national security and strengthening the national economy. No scientific effort is more critical to serving both objectives than is the mission-oriented research of ARS. A flagging agricultural technology—costly and erratic food supplies and depleted natural resources—is not in the national interest. Food is as critical to national security as are armaments. Agriculture, the Nation's largest industry, is in serious economic difficulty, and ways must be sought to restore its prosperity and to ensure its long-term stability.

The resources of ARS provide a sound foundation for developing the means by which agricultural technology may meet the enormous demands of future years. Those resources are as follows:

- *Critical mass of scientific capabilities,* comprised of more than 2,700 scientists and engineers, plus technical support staff, with the knowledge, technical expertise, and specialized scientific equipment to respond to broad regional and national problems.

- *Unique facilities and laboratories,* developed for all the disciplines demanded by agricultural research. Many are highly specialized laboratories; for example, those for the study of exotic diseases of plants and animals. Facilities are located strategically across the major farm and rangeland ecosystems and climatic zones of the United States. The world's largest multidisciplinary agricultural research center is at Beltsville, Md.

- *Organizational capability and central management to assemble resources,* including interdisciplinary teams to address broad geographic problems, the research needs of action agencies and other Federal organizations, and other high-priority needs for knowledge and technology. ARS has institutional arrangements for working with State Agricultural Experiment Stations, industrial research institutions, and others to bring outside talents and resources to bear on problem solving. The ARS also maintains international activities to mobilize the talents of foreign scientists and laboratories.

- *Unique germplasm collections and repositories of species of agricultural importance,* including world collections of most of the major crop plants and many potential new crops, clonal repositories, disease-free seed stocks, collections of microbes and insects, and unique herds and flocks of animals.

The ARS is challenged to manage its resources efficiently and effectively. In response to that challenge, it must assure the Nation that the Federal commitment to agricultural research is sufficient to deliver the science and technology that are essential to meet the continuing, long-term needs of national and world agriculture.

e ARS Program Plan

As illustrated in figure 4, the ARS Program Plan is the result of strategic and operational planning. This document describes the Program Strategy of strategic planning. It also introduces the Implementation Strategy by presenting the six major policies of the Agency. Based on the Program Strategy and those policies, a Six-Year Implementation Plan and resource projections are being prepared. They, in turn, will guide operational planning, resource allocation, and program execution for achieving the six objectives. Thus, this Program Plan will enable the ARS to mobilize its resources—talent and facilities—in a united effort to achieve its goal and to serve the U.S. agricultural enterprise.

As a Federal agency, ARS concentrates on research problems that are high-risk, long-range, and of national or regional scope. Such research requires unified planning, continuity of effort, a stable scientific environment, and the ability and flexibility to commit the necessary resources to high-priority needs that only a centrally funded, national organization can address. In accordance with its mission, the ARS also must continue to meet its responsibilities to support quarantine and other action programs, foreign policy initiatives, important national and international germplasm collections, and special emergency programs of regional or national significance. The need to integrate those responsibilities into the ARS program, with its disciplinary research in support of the six objectives, emphasizes the requirement for a planned and centrally managed operation.

Few people realize the technical and scientific complexity of the business of food and agriculture. The research programs of ARS must address that complexity in a logical and consistent manner. The success of the Nation's agriculture is influenced by an array of complex problems that can be physical or biological, and the scientific responsibilities of ARS must span the whole array for effective discharge of its assigned responsibilities.

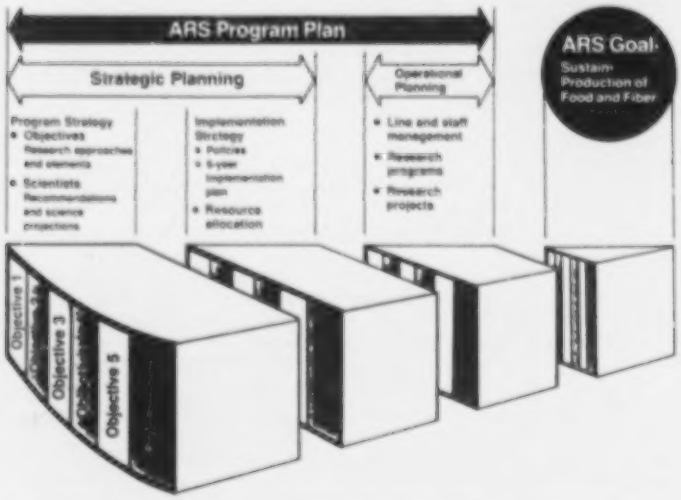


FIGURE 4.—The relationship of strategic and operational planning to the ARS goal and objectives.

As illustrated in figure 5, the Program Strategy of the ARS Program Plan was designed around a goal that is addressed by six objectives; progress on the objectives will result in progress toward the goal. With that design, all levels of organization, from individual laboratories to headquarters staffs and administrators, can use the Plan; all phases of research—ranging from studies of plant and animal genes to studies of bread and meat—can contribute to the goal.

Planning by ARS is an ongoing process, and through annual updating to reflect changes in priorities, appropriations, personnel shifts, and new research findings, the Plan will remain a dynamic document. The Six-Year Implementation Plan will be used by management as a baseline for evaluating progress and reallocating resources.

Line managers and members of the National Program Staff (NPS) developed the following goal and objectives for the Agency. They considered authorizing legislation, policy statements from the Secretary and the Assistant Secretary for Science and Education of the Department, and the common program structure developed by the Joint Council on Food and Agricultural Sciences.

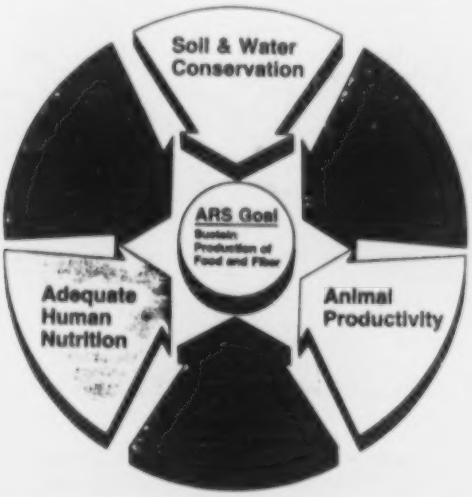


FIGURE 5.—The ARS Program Strategy—goal and objectives.

Goal:
Through fundamental and applied research, ARS seeks to provide the means for solving the technical food and agricultural problems of broad scope and high national priority as required to ensure, perpetually, an adequate supply of high-quality food and fiber for the American people and for export.

Objectives:
Develop the means for—

1. Managing and conserving the Nation's soil and water resources for a stable and productive agriculture;

2. Maintaining and increasing the productivity and quality of crop plants;

3. Increasing the productivity of animals and the quality of animal products;

4. Achieving maximum use of agricultural products for domestic markets and export;

5. Promoting optimum human health and well-being through improved nutrition and family resource management; and

6. Integrating scientific knowledge of agricultural production, processing, and marketing into systems that optimize resource management and facilitate transfer of technology to users.

The six objectives describe the aims of ARS science. The words "develop the means for" are important. The ARS is a research agency; farmers and ranchers, action agencies, and the private section will actually achieve the stated objectives. The ARS is not the only agricultural research organization working on these or related objectives. The State Agricultural Experiment Stations and Land-Grant Universities contribute to them. Each State also has a Cooperative Extension Service office, Soil Conservation Service offices, and other organizations to help transfer research findings to users. Other Federal agencies, non-Land-Grant Universities, private foundations, and other institutions conduct research on problems that are important to food and agriculture. Industrial organizations conduct research on farming equipment, crops and livestock, agrichemicals, pharmaceuticals, product improvement, marketing, and nutrition—to name but a few. The ARS Program Plan will ensure that our research complements and supports, rather than duplicates, those other efforts.

All six objectives are essential, and achieving them wholly or in part will help meet the stated goal. Conservation and restoration can ensure that the resource base remains adequate for future generations. Increasing the productivity of our crop plants and livestock should help ensure farmers' margin of profit and provide food and fiber to consumers at reasonable costs. Producing food and fiber crops, however, is not enough; raw materials must be processed and delivered in an efficient and timely manner for ultimate consumption. Through all stages of production, marketing, and consumption, products must be protected against losses from diseases and from insects and other pests. Just as important are the safety, wholesomeness, and quality of the products, especially of the basic foodstuffs. Finally, total management systems must be developed to integrate and optimize the use of all basic resources and production factors to ensure that food and other agricultural necessities will be available.

This ARS Program Plan identifies and explains the main problems that confront the agricultural industry and charts the minimum courses of action that will provide the research needed for solutions to the problems. The current ARS budget of about $450 million annually has approximately the same purchasing power as did the 1966 budget. Clearly, the kinds of numbers of projects that can be undertaken within 1966 budget levels are limited. Hard choices must be made. Seventy percent of the members of the ARS scientific staff are 40 years of age or older. That figure implies that turnover and loss of specialists with experience will be extensive during the next few years. We also face a shortage of young, recently trained engineers, computer scientists, biophysicists, molecular biologists, and other critical specialists in the rapidly evolving disciplines needed to solve the problems of the future. To fulfill the Federal commitment of delivering the science and technology that are essential to meet continuing, long-term needs of agriculture, the ARS must maintain a research climate that attracts and retains the best scientists and creative thinkers.

In the past, especially during times of surpluses, various people have argued that production research should be stopped, or at least deemphasized. Conversely, during emergencies or times of shortages, researchers are asked to supply immediate solutions. Research cannot be turned on and off like a water faucet. Stability and long-term commitments are required. For example, research on Marek's disease of poultry caused by a tumor virus was initiated in 1939. The causative virus was not isolated until 1967, and a vaccine was licensed for national use in 1971. By 1974 the annual benefit from the vaccine was $180 million, at a total cost of $31 million in public research funds. Many examples of long lead times can be given for other kinds of technologies, as well as high rates of return from use of the technologies.

The ARS Program Strategy

Agricultural science has been characterized as "the mother of sciences" in recognition of its early development and profound influence on both science and society. We have a vast knowledge base for managing resources, producing crops and livestock, and processing and transporting food and fiber. Some scientists and policymakers, however, question whether our agricultural industry can meet long-term national and export needs and whether ARS, as a research agency, can develop the new technology that would be essential for meeting those long-term needs. The design of the ARS Program Strategy provides for building most effectively on our present scientific knowledge base to identify and pursue the most promising research opportunities, thereby promoting the research that produces entirely new knowledge and technologies. We intend to balance the activities of our program across the spectrum of agricultural research; we will identify the most promising research opportunities, both basic and applied, by considering the supporting knowledge base, the probability of success, and the potential impact of success on our efforts to meet future national agricultural needs.

Overall Research Strategies

Strategies for future production of food and fiber must identify the research that has the highest potential for achieving our objectives through alternative courses of action. The limits of productive capacity that are imposed by current technologies and finite natural resources are real, and they probably will become constraining as they are surpassed by demand. We must conserve our natural resources for future generations. The possibility of substantially increasing food supplies is based on the assumption that we can develop totally new technologies that might increase the efficiency with which plants use the sun's energy to convert soil nutrients, fertilizer, and water into food for humans. In some biotechnological approaches, plants would be replaced by another means of synthesizing food. We may need such revolutionary technologies if we are to reduce the amount of natural resources used in producing food and fiber. Equally important will be the development of improved technologies to augment existing systems for production of plants and animals. Development of revolutionary technologies will take time, and we should get started, but we must temper our optimism about revolutionary technologies. So far we have produced very few, and we must not risk diversion of all our effort from tested and proved research approaches. While we explore new technologies that might rescue us from our dependence on nonrenewable resources, we must intensify our efforts to maintain and improve the productive capability of our agricultural systems.

We need to help farmers and ranchers escape their current economic dilemma—net incomes that are comparable to those of the 1930's. Those independent entrepreneurs, the primary producers of food and fiber, must have an economic environment in which they realize sufficient return, and—thereby—incentive, to incorporate new methods and technologies into their production practices. Only farmers and ranchers who are financially strong can afford the risk of testing new methods in their operations. No national agricultural strategy will succeed unless farmers realize profit. The information produced by research can help not only to reduce production costs, but also to improve economic and political decisions related to agriculture.

Three broad strategies thus emerge for ensuring national security in terms of the quantity and quality of future food and fiber supplies. Those three strategies are represented at different points in each of the six objectives. They are—

- Develop knowledge of and technology for conserving and protecting our endowment of basic resources such as germplasm, soil, and water.

- Develop knowledge of and technology for exploiting known production potentials by closing the gap between average and record yields, reducing losses, and improving the efficiency of current production and marketing systems.

- Develop totally new technologies for producing, processing, and marketing the vast quantities of food, fiber, and other agricultural products that will be needed in the next century and beyond.

The Program Strategy is based on science. The ideas and recommendations of approximately 500 ARS scientists and members of the NPS are summarized in the objectives presented and discussed on the following pages. Research approaches and approach elements that outline the scientific efforts needed to achieve the ARS goal are presented in each objective. The approaches and elements define research strategies and do not necessarily represent current or planned operating programs. Individual programs are, and will continue to be, organized in a manner that facilitates effective management and use of resources. The flexibility to mobilize resources quickly to take advantage of new research findings is of paramount importance.

The Program Strategy describes the minimum number of scientific approaches needed to accomplish the goal. However, all approaches or approach elements may not be given equal support. Priorities will be set by the Deputy Administrator of ARS after he weighs the availability of resources, needs of agriculture, scientific progress, and other criteria. The Administrator will ensure that the priorities are consistent with the goals of the Department. The highest priority portions of the Program Strategy will be included in the Six-Year Implementation Plan for execution by line managers and scientists. In this manner, ARS will help ensure that the best possible science is available to support agriculture. At all times, the ARS will coordinate its efforts with the State Agricultural Experiment Stations, industry, and others who conduct research on these or similar objectives to help ensure that the efforts are complementary. Meeting the research needs of action agencies and policy groups within USDA will have high priority within all six objectives.

Objective 1
Develop the Means for Managing and Conserving the Nation's Soil and Water Resources for a Stable and Productive Agriculture

Natural resources are the foundation of agricultural productivity. The United States has an abundance of productive soil, water, and related air and climatic resources, but the rate of increase in agricultural productivity apparently is declining. Several causes for that decline are related to the quantity and quality of our natural resources. Erosion, a major problem on nearly one-third of our Nation's croplands, not only destroys inherent soil fertility and productivity, but also pollutes water supplies and fills reservoirs and lakes with sediments that are laden with chemicals and nutrients. Of our rangeland, 60 percent is in only poor to fair condition and produces less than half its potential. Ground-water supplies are being depleted in large areas of the Southern Plains and the Southwest. Increased salinity results in costs to both agriculture and municipalities; in the Colorado River basin alone, damages were estimated at $53 million in the 1973 but are expected to reach $150 million annually by the year 2000 unless salt loading can be controlled. Flood damage to downstream property, estimated at $3.4 billion in 1975, is also increasing. Evidence indicates that air pollution reduces productivity more than previously suspected, and damage in the Ohio Valley alone is projected at $8.3 billion by the year 2000. About 3 million acres of farmlands, nearly one-third of which is prime land, is diverted to nonagricultural uses each year. Water, too, is diverted from agricultural to urban and industrial uses, and competition for water is increasing.

We have recovered some of the productivity lost because of damage to our natural resources in the past by investing capital in conservation practices and irrigation and drainage systems and by applying new agricultural technology. Millions of acres of croplands have been improved or reclaimed by the use of lime and fertilizers, soil conservation, and improved water management. Those same technologies, however, along with improved crop varieties and pest control, tend to mask the continuing degradation of

our soil, water, and air resources. Eventually, those technologies will not compensate adequately for the losses in productivity that result from resource degradation, either because of physical limitations—such as decreasing soil depth—or because of economic limitations caused by the high costs of fertilizer, fuel, and other inputs.

Recent resource assessments by USDA, Congress, and others indicate that the United States is reaching the limit of additional land and water supplies that can be developed economically. Among the factors limiting that development are the high cost of energy, high interest rates, and climatic and soil constraints. Available irrigation water will decrease in several Western States because of ground-water mining and increased competition from nonagricultural users. Because plants lose such large amounts of water during photosynthesis, agriculture cannot compete with other industries. Agriculture requires roughly 100 times as much water to produce products of a given value as does the nonagricultural sector. Moreover, much of the additional land available for croplands, about 130 million acres, is fragile and highly susceptible to erosion or already produces forage and timber. Most of the sustainable future increases in production must, therefore, depend not on an expanding acreage, but—rather—on protecting, restoring, or improving soil productivity, improving crop and forage yields, and using existing water supplies more efficiently.

We must develop and adopt innovative and improved approaches to the evaluation and use of resources and to other factors that are critical to productivity if we are to sustain, much less to increase, the agricultural productivity of our resources. Research findings for use by farmers and ranchers, Extension personnel, private industry, action agencies such as the Soil Conservation Service, and many others are the key to new technology for achieving our goal. The research priorities for the Nation that recently were identified by about 100 of the Nation's leading conservationists emphasize long-term national needs, particularly research concerned with the care and maintenance of our soil and water resources. To meet those research priorities, we must increase our commitment to basic research to restock our storehouse of fundamental knowledge.

Approach 1.1 **Develop the Technology for Assessing and Predicting Long-Term Changes in the Quantity and Quality of Soil, Water, and Air Resources Available to Agriculture.**

Approach Elements

1.1.1 *Develop improved techniques and systems for assessing, predicting, and monitoring changes in the productive capacity of land and soil resources.*

1.1.2 *Develop improved techniques for assessing and predicting water supplies and their quality.*

1.1.3 *Develop improved techniques for assessing and predicting the effects of weather and air quality on agricultural productivity.*

18

57-279 O - 87 - 35

Our future food-production systems depend upon continuing supplies of fertile soil, good-quality water, clean air, and a favorable climate for plant and animal growth. The supply of natural resources available to the United States for plant and animal growth is finite, and we must take steps now to provide for continued availability and sustained productivity of those resources for future generations.

We urgently need improved technology for assessing our present land resource base and for defining its inherent productive capacity as the basis for development of optimum conservation practices and sound national policies on the management of croplands and rangelands. The United States has about 10,000 kinds of soil that differ in their physical, chemical, and biological properties and in their responses to cultural inputs. Perfecting and using new techniques, such as remote sensing and computerized data collection, to measure those properties and assess their importance can speed information flow and reduce costs. The current system of soil classification provides data and an initial framework for developing the systems needed for measuring and comparing the effects of different management practices on erosion and productivity for diverse soils, climates, and topographies.

We also need improved technology for assessing changes in the quantity and quality of water resources. As the competition for water grows, accurate and timely information about changes will be vital for making the best use of that resource, which generally is the most limiting factor in agriculture. Only one of many examples is the need to assess the effectivenss of action programs for reducing salt loading in the Colorado River. Better management of our water resources requires improved technology for determining the spatial and temporal distributions of precipitation and for evaluating their effects on the quantity and quality of surface and ground-water supplies. Except in areas with large ground-water supplies, climatic factors largely determine water supply for agricultural production. Variations in weather from year to year modify crop productivity, but long-term climatic differences among physiographic regions are largely responsible for regional differences in soil productivity. Technology for accurately assessing the effects of weather on croplands and rangelands must be improved so that conservation and production strategies at farm, State, and national levels can be optimized.

Recent research has shown that some air pollutants, such as ozone, always reduce crop yields. Sulfur dioxide may either decrease or increase yields and soil productivity, depending upon its concentration in the air and the buffering capacity and nutrient status of soils. Increases in carbon dioxide consistently increase crop yields in greenhouse and growth chambers. We need technology for assessing the long-term effects of projected changes in the concentration of those atmospheric constituents on crop and soil productivity.

Improved technology, such as remote sensing, also is needed for monitoring changes in land use, soil and crop status, and soil- and crop-management practices and for assessing their effects on overall productivity. Improved technology will enable more accurate predictions of national and global production of key agricultural commodities and provide early warning of commodity shortages. Those predictions, in turn, will permit better management of our resources, provide useful marketing information, and aid in the development of sound production and marketing policies.

Approach 1.2

Provide the Technology Needed for Improving, Protecting, and Restoring the Productive Capacity of Agricultural Soils.

Approach Elements

1.2.1 *Develop cost-effective conservation technologies for controlling soil loss from croplands and rangelands.*

1.2.2 *Devise methods for maintaining and improving soil fertility and the chemical and biological properties of soils for optimum crop production.*

1.2.3 *Devise techniques for improving, maintaining, or restoring the physical conditions of soils that are needed for optimum crop production.*

1.2.4 *Devise methods for safety and efficiently recycling municipal and agricultural wastes through croplands.*

Soils, the reservoirs that store the water and plant nutrients that are needed for crop production, also provide the chemical, physical, and biological environment for seed germination, plant establishment, and root growth. Because erosion of soil impairs those functions, we need a fundamental understanding of the physical processes by which wind and water erode soil. We need an integrated research program as a basis for developing highly efficient, cost-effective systems of tillage and conservation practices for control of wind and water erosion. Those systems must be tailored to the specific requirements of each of the many combinations of soils, crops, and climatic zones in the United States.

We must also improve the practices for restoring the fertility of eroded, mined, and marginal lands, as well as for maintaining the fertility of prime agricultural lands. We should direct substantial research effort toward the management of fertilizers. Increasing the efficiency of nitrogen fertilizer from 50 to at least 75 percent would help reduce the impact of the escalating costs of agricultural chemicals on farm income. Enhancement of nutrient availability in soil, of nutrient cycling from agricultural and other wastes, and of the biological environment in soil also could improve fertilizer-use efficiency. Biological nitrogen fixation can reduce the need for fertilizer nitrogen in some cropping systems. To ameliorate the negative effects that adverse chemical and biological conditions in soil have on the productivity and nutritional quality of plants, we need a better understanding of how minerals, including toxic elements, move from soils into plants. We also need to study how pesticides affect the biological properties of soils and their ability to cycle and release plant nutrients. Large quantities of crop residues adversely affect plant growth by releasing phytotoxic compounds during decomposition; those reactions must be understood for effectively managing minimum- and no-till systems. The development of basic knowledge of soil-plant relationships is one key to future technology for improving soil productivity and eliminating barriers that limit crop yields.

Adverse soil conditions such as low water-holding capacity and permeability, compaction, low temperature, and deficient aeration often limit production. Such conditions could be corrected by improved soil-management systems, including conservation tillage and crop-residue management. However, we need basic studies on the causes of poor

soil conditions and on machine-soil dynamics as a basis for defining optimum conditions for the root zone and for designing practices that will ameliorate adverse soil conditions. We also need to better understand soil microbiology and chemistry so that we can specify safe and efficient practices for recycling municipal and agricultural wastes through croplands. Properly used, those wastes could enhance the productive capacity of soils. The recycling of wastes could salvage valuable water and nutrients and provide organic matter to improve the chemical, physical, and biological properties of soils.

Approach 1.3 **Develop Improved Water-Management Systems and Practices To Achieve Effective and Efficient Use of Water Resources.**

Approach Elements

1.3.1 *Optimize the use of water by plants in irrigated and nonirrigated croplands and rangelands to improve and stabilize productivity.*

1.3.2 *Develop methods for increasing, conserving, and managing water supplies available for agriculture, for improving water quality, and for reducing cropland damage from flooding.*

1.3.3 *Improve technology for storing and distributing water supplies efficiently and for improving irrigation, drainage, and salinity-control systems and practices.*

Water is a key resource for agricultural production, and crop yields are reduced more frequently and severely by water stress than by any other environmental factor. Of about 800 million acre-feet of water that evaporates from U.S. croplands each year, precipitation supplies 700 million acre-feet and irrigation supplies 100 million acre-feet. About 20 million acre-feet of the water used for irrigation is from ground-water reserves, and about 70 percent of that water is drawn from the Ogallala aquifer in the Southern Great Plains, which now supports about 20 percent of the U.S. crops that are exported. Large amounts of water are used by nonagricultural trees and plants, lost by evaporation from lakes and reservoirs, or discharged into the ocean in water-short areas of the arid Southwest. For example, phreatophytes, such as salt cedar, consume an estimated 25 million acre-feet of water annually, of which two-thirds could be conserved for agricultural use. Annual evaporative losses from lakes and reservoirs in the arid West total more than 16 million acre-feet. Several million acre-feet of moderately saline water that could be used for producing salt-tolerant crops is now discharged to salt sinks or to the ocean each year. In the future, we will need to manage water much more efficiently than we do now.

The development of technology for increasing water-use efficiency of crops and ranges (production per unit of water consumed) by 25 to 50 percent during the next two decades requires an integrated program of fundamental and applied research directed toward a better understanding of the response of both irrigated and nonirrigated crops to water stress at various growth stages. Also needed is improved technology for increasing storage of rainfall and snowmelt in soils through such means as controlling runoff, increasing infiltration, and reducing evaporation. Such technology is crucial for high production of rangelands and of dryland crops. By using available water supplies more

efficiently on croplands and rangelands, we can increase total crop and livestock production, reduce the year-to-year variations in yield caused by droughts, and reduce production costs on irrigated lands.

The quantity and quality of water supplies for irrigation and other uses depend upon the management of complex watershed systems. We need to develop an integrated research program on effectively managing and, in some cases, increasing the yield of water from croplands and rangelands by improved management of snow and vegetation. We also need to develop improved low-cost structures and practices for control of flooding, ground-water recharge, water quality, and reservoir sedimentation. We need improved technology for economical water harvesting and runoff farming in arid areas. Particularly needed is improved technology for predicting—for major physiographic areas—the effects of land use and land treatment on water yield and quality, ground-water recharge, base flow, and the frequency and severity of flooding.

Of the water diverted for irrigation, nearly 26 million acre-feet is lost annually by seepage in conveyance systems and a similar amount is lost to deep percolation and surface runoff. Some of that water is recovered for reuse in irrigated valleys, but most of the loss from irrigated areas that are adjacent to oceans, inland seas, and salt sinks is permanent. Essentially, all deep percolation from excess water applied on irrigated lands that are underlain by deep, dry sediments is unavailable for future use. We need to develop low-cost methods for controlling seepage and improving the efficiency of water-distribution systems. We also need improved systems and operating criteria that will enable project managers to deliver, and farmers to use, precisely the right amount of water at the right time.

Improved drainage technologies are also needed to avoid overdrainage of coarse-textured soils, minimize crop stress caused by excess water, improve trafficability, prevent salinization of irrigated soils, and increase the production potential of cold, wet soils. Declines of investments in cropland drainage in recent years could be a significant cause of reduced soil produtivity.

Approach 1.4 **Develop Subsystems and Models That Integrate the Use of Soil, Water, and Air Resources for Optimum Management of Major Land Resource Areas.**

Approach Elements

1.4.1 *Develop systems and models for designing resource management strategies that optimize agricultural production and resource conservation.*

1.4.2 *Develop systems and models for designing resource management strategies that will satisfy the needs of nonagricultural resource uses.*

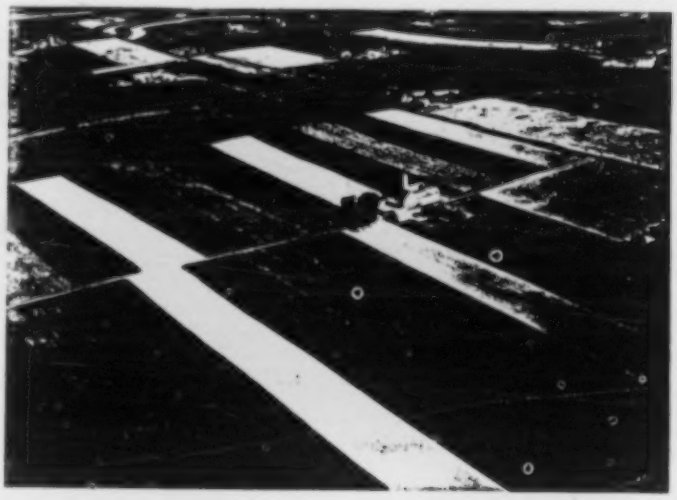
1.4.3 *Develop systems and models for designing resource management strategies that are compatible with environmental quality goals.*

Objective 6 describes user-oriented systems and models that optimize the management of land, germplasm, energy, and other resources for efficient and effective production. Models and subsystems should be developed for the simulation of alternative ways to manage each of the variables. Because the soil, water, and atmospheric components of the agricultural system are so intimately intertwined, the management of one component without influencing or considering the influence of the other components is practically impossible. For example, water and air occupy the airspace within soil in reciprocal proportions; the wetter the soil, the less air it contains, and vice versa. The water content of soil has a major influence on soil temperature.

Some plant nutrients remain dissolved in the soil water and, therefore, move with it. Other nutrients, as well as most organic pesticides and heavy-metal contaminants, are strongly adsorbed on the surfaces of soil particles and, therefore, move only slowly with the soil water. Because the surfaces of clay particles within the soil carry net electric charges, they participate in important chemical reactions. The chemical and physical properties of soil, along with its contents of water and air, largely determine its biological capacity. Plant roots are the most important biotic systems in soils, but microorganisms are important in fixing nitrogen from the air into a form usable by crops, in recycling nutrients from crop and other residues and, in some instances, in facilitating nutrient uptake by roots. Simulation models can be used in predicting the effects of different management practices and in designing improved practices for producing crops and protecting water quality.

In general, agriculture must adapt to, rather than manage, weather and air quality; soil capacity influences the success of that adaptation. Deep, porous soils that effectively absorb and store rainfall are less vulnerable to drought than are shallow soils. Soil capacity, a primary factor in determining fertilizer requirements and stability of crop production in rain-fed agricultural regions, is reduced by soil erosion. Frequent irrigation and fertilization compensate for reduced capacity of the soil to store water and nutrients, but at a cost. We need to develop new and improved management systems for conserving resources and optimizing their use for the long term. Farmers and ranchers control more of our environment than does any other group of people, and they must have the knowledge and techniques to manage the environment wisely.

Objective 2
Develop the Means for Maintaining and Increasing the Productivity and Quality of Crop Plants



Projected long-term demands for the production of our major crops cannot be met with current yields and, for some crops, could not be met even with the highest experimental yields ever achieved. Meeting those demands is as important and as challenging as providing for national defense, finding new energy supplies, and solving other national problems. We must not only meet our own needs for adequate and nutritious food, but also contribute to the nutritional needs of developing countries until they can grow their own food. Further, sales of food and other agricultural products to industrial nations provide markets for farmers and help balance our foreign trade deficit. We do not know that the projected demands can be met, but, to have the best chance, we must develop strategies for breaking down some fundamental barriers that limit crop productivity. We must also explore possibilities of developing new crops and better methods of controlling the losses from all of our crops.

The foundation of crop productivity is the inherent genetic potential of the plants, themselves. Essentially all the crops we grow and use for food and fiber originated outside the United States. Thus, to ensure a full complement of genetic potential and diversity, and to protect against the kind of vulnerability we experienced with the southern corn leaf blight in 1970, we must have programs for the systematic introduction, evaluation, and development of crop germplasm. As the countries where our crop plants originated develop economically and adopt modern varieties of those plants, folk varieties and wild types are being lost. Once lost, plant germplasm cannot be reconstructed and sources of resistance to disease epidemic or extreme drought could be lost forever. Diverse sources of germplasm also exist for beneficial insects, micro-organisms, and other useful biological materials. Such organisms and materials often hold the key to biological control of pests, and some could supply genes for totally new biotechnologies.

Genetic composition is expressed through its interactions with the environment, including weather, soils, diseases, insects, and many other variables, and many sources of germplasm must be evaluated and screened for use in breeding programs. Then, genes that exhibit desirable traits must be characterized, classified, and preserved. Knowledge of biosystematic or taxonomic relationships within the plant and animal kingdoms is essential for both breeding and pest-control programs. We must make this continuum, from source to end use, of plant genes fully functional and maintain balance to improve productivity, quality, and other desired characteristics of crops. The ARS plays a major role in this continuum and, in a sense, is the steward of the Nation's crop germplasm. A prominent ARS geneticist summarized succinctly, as follows: "When embarking on a voyage into a future as uncertain as ours, we must be sure to take along our seeds."

Anyone who gardens knowns the complexity of growing crops. After selecting the best hybrids or cultivars for their climates, farmers face a multitude of decisions for each crop throughout the growing season. They decide, for example, time of planting, spacing of the rows, depth of planting, and number of seeds per acre. Later, they decide how much and when to fertilize, irrigate, or cultivate. Critical decisions also must be made about harvesting. After harvest and before replanting, they must decide the timing and kind of primary tillage needed to protect the soil and prepare for the next crop. Throughout the year, farmers also must select the materials and methods that will best protect crops against weeds, insects, diseases, and other pests that can rob them of all profits. Nearly all of those activities are interrelated and must be scheduled carefully to produce top yields and quality. One mistake often can make the difference between profit and loss. Finding the best combinations of all those practices for each crop and climatic zone is a formidable research task that requires close coordination and working relationships among scientists in ARS, in State Experiment Stations, and in industry. As the limits of productivity are approached, we must increase our basic and applied research to develop cultural and management practices that will consistently produce high yields. Those practices must also be cost-effective.

In the United States, pests destroy one-third of the potential harvest, or about $35 billion worth of products. Pests are legion and include about 10,000 species of insects, 8,000 fungi, 2,000 weeds, and other assorted organisms. To increase productivity, we must control pests. However, control is complex and costly, and experience indicates that it will become much more difficult as we try to wring higher yields from the land. We often control one pest only to find that another prospers in its ecological niche. Organisms may develop resistance to chemicals. Many pest-resistant crop varieties become obsolete in only 3 to 10 years because the mechanism of resistance is overcome by new strains and biotypes of pests. Just to stay even, researchers must race to develop new varieties and protection technologies. We will need totally new approaches to crop protection if we hope to permanently manage the competition from weeds, diseases, insects, nematodes, and vertebrate pests. As growers adopt new technology and practices, such as minimum tillage, scientists are challenged to develop new methods for control of predators and weeds. When farmers convert from a conventional sequence of practices—crop, cultivate, fallow—to minimum-tillage practices, the land's ecology undergoes ma-

jor changes. Weeds, diseases, and predators that were of no economic significance under conventional practices can become so competitive that traditional practices and plant germplasm will no longer protect yields. Then, scientists must develop new, cost-effective materials and methods to meet the new needs.

We also must try to reduce the costs of pest control that now total about $10 billion per year. Another important concern is the prevention of the potentially adverse environmental effects of both the pests and the methods used to combat them. To deal effectively with those and other concerns, we will test alternative courses of action by computerized systems analysis. For example, we will develop and study subsystems for individual crops and pests and then integrate those subsystems into multiple-crop and multiple-pest systems. Thus, by simulating complex systems, we will be able to predict their biological and physical effects on plants, pests, and the environment and to select the best course of action. Systems analysis will also be needed to identify the barriers, in addition to pests, that limit crop productivity. As an example, such analysis might help us to identify the factor that now limits plants' use of available solar radiation to only 1-2 percent, although the estimated potential is closer to 10 percent.

The need for more emphasis on basis research permeates all aspects of crop productivity. During the past decade, knowledge of and new techniques for manipulating the genetic composition of micro-organisms have advanced dramatically. Those advances strongly suggest that genetic manipulation of higher plants could open the door for totally new kinds of biological materials and technologies. That opportunity must be explored, and exploited if possible, through basic research to determine the ways in which genes code for inheritance, genetic messages are expressed in basic processes, and environment modulates genetic expression. Basic knowledge concerning such factors will be needed if we are to break through the limits on productivity now imposed by pests, finite natural resources, and environmental stresses and are to benefit from the full potential of available germplasm. Examples of possible advances are cereal crops that would provide their own nitrogen through biological nitrogen fixation and plants with a genetic makeup that discourages attack by insects, pathogens, and nematodes.

Approach 2.1 **Broaden the Germplasm Resources of Plants and Beneficial Organisms To Ensure Maximum Genetic Diversity for Improved Productivity.**

Approach Elements

2.1.1 *Develop an understanding of the taxonomic relationships among plants, beneficial organisms, and pests as the basis for research to enhance crop production and protection.*

2.1.2 *Collect, evaluate, preserve, and make accessible new sources of germplasm of plants and other organisms and assess their potential for meeting agricultural and industrial needs.*

2.1.3 *Collect, evaluate, preserve, and distribute germplasm of plants and beneficial organisms and of strains of pests that are valuable in pest-management programs.*

Plant germplasm is the base for productive agriculture. It is the genetic raw material that breeders use to develop new, superior crop varieties that can ensure a stable, plentiful supply of high-quality food, feed, and fiber. Only a broad base of plant germplasm can provide the genetic diversity that farmers and public and private plant scientists need to improve the quality and productivity of crops and to minimize their vulnerability to biological and environmental stresses. Crops become vulnerable when stresses from diseases, insects, drought, or temperature extremes exceed the crops' ranges of tolerance or resistance to such factors. The results can vary from localized yield reduction to disastrous crop failures over large areas. Protection from crop losses through control of biological and environmental stresses is far more difficult and costly than is protection through increased genetic diversity among varieties of a given crop. In the former method, we attempt to change the environment to meet the needs of the crop; in the latter, we attempt to change the crop to cope with the environment. We must, therefore, broaden the genetic diversity of crops throughout their production areas by developing—from an array of genetic populations—cultivars that are alike in their productivity, but different in their sources and ranges of tolerance to one or more stresses. Such cultivars could reduce the likelihood of epidemic losses.

An area of special need is a systematic exploration of the plant world for potentially valuable new crops and sources of raw materials for industrial and medical uses. Of the more than 300,000 plant species that nature offers, we now use only about 150 in agriculture. No one knows the potential of most of the neglected plants for tolerance to environmental extremes or for producing needed oils, proteins, gums, waxes, drugs, or other useful materials. The potential of those plants for producing strategic materials and making the United States self-sufficient must be assessed.

Similarly, the world offers a vast resource of diverse germplasm of beneficial parasites, predators, micro-organisms, and nematodes. Judicious introduction of selected species, varieties, and strains of organisms from those sources has led to the control of some pests and a significant reduction in production costs. The use of biological control practices as part of our integrated pest management (IPM) strategy holds great promise for the future.

Taxonomic services and research provide fundamental knowledge for basic research in the protection and production of animals and plants. Taxonomy (or systematics) is essential in the research and development of biological control, IPM, regulatory and quarantine activities, alternative and new crops, genetic selection and manipulation, and industrial uses of micro-organisms. Further, the predictive powers of classifications guide exploration and experimentation in the most promising direction; for example, as in the search for natural enemies of pests or for the origin of genetic diversity of potential new crops. Because agricultural, biological, environmental, and health sciences require prompt input of taxonomic data, and because the classification of the estimated 10 million animal and plant species is far from complete, many taxonomic specialists are

needed. Unique and vast resources (specimen reference collections and extensive published and unpublished information) must be physically maintained. Also, the information must be computerized for rapid delivery to and use by a diverse clientele in the development of new research. For efficient utilization and protection of our flora and fauna, we must have the holistic knowledge of their natural relationships that only a solid program of biosystematic research can provide.

Approach 2.2 **Select and Modify Germplasm of Plants, Beneficial Organisms, and Pests.**

Approach Elements

2.2.1 *Devise new methods for modifying germplasm of plants, beneficial organisms, and pests.*

2.2.2 *Improve genetic populations of range, pasture, forage, and turf.*

2.2.3 *Improve genetic populations of field crops.*

2.2.4 *Improve genetic populations of horticultural and specialty crops.*

2.2.5 *Improve genetic populations of beneficial organisms, and develop inferior strains of pests that will be useful in pest-management programs.*

The procedures for selecting and modifying plants and beneficial organisms are similar, particularly for range, forage, field, horticultural, and specialty crops. For the purposes of these discussions, in objective 2 no effort will be made to address production or protection procedures on a crop-by-crop basis.

Developing crops that are well adapted to their environments and have desirable nutritional or commercial quality is a long and costly process. Many steps are involved—from the most basic genetic research to maintenance of breeder stocks. Decades may be required to incorporate a desired quality into an adapted crop plant. In contrast, a commercial variety or hybrid may last only a few years before succumbing to a disease organism or insect. For those reasons, plant-improvement programs must have stability and continuity and remain vigorous in the foreseeable future.

Once genetic resources have been screened, genes for the desirable traits that are identified must be combined into improved strains that will be useful to breeders and, eventually, to growers. Resistance to pests, tolerance to cold or drought, high protein content, early maturity, and a host of other desirable features are needed for commercial production. However, those traits rarely are found together, and they may be found in stocks that are unsuited for cultivation. In developmental breeding, which ties together the work of germplasm collection, screening, and gentic analysis, scientists sort—from the many objectives or traits that might be pursued—those with a high probability of success.

Candidate strains and varieties are evaluated through replicated performance trials over several years and several locations. For valid assessments, they must be tested with many combinations of soils, nutrient levels, diseases, insects, weather, cultural practices, and harvesting methods. Only by stringent evaluation of candidates can genetic yield potential keep pace with the increasing demands and complexity of crop production and marketing systems. In recent years, especially with advances in genetic engineering, increased emphasis has been placed on finding ways to shorten the process of crop improvement and to make it more efficient and less costly. However, we should recognize that crop-improvement programs, although slow, have been exceedingly successful and form a solid foundation for the whole agricultural industry.

Emphasis on finding biological agents for pest control has increased. The use of parasites, predators, pathogens, and other kinds of agents as a single tactic or as part of an integrated program offers the potential for pest control that would be economical, energy saving, environmentally safe, and—often—permanent. Such technology is in its infancy, however, and we need much additional research to increase the arsenal of natural enemies. Expanded foreign exploration, quarantine research laboratories, and basic ecological studies will be required.

pproach 2.3 **Develop Improved Production Practices for Maintaining and Increasing Crop Productivity and Quality and for Reducing Costs.**

Approach Elements

2.3.1 *Develop knowledge of basic plant growth and development processes of crop species and of micro-organisms of agricultural importance.*

2.3.2 *Develop basic ecological principles and improved cultural and management practices for range, pasture, and forage.*

2.3.3 *Develop basic ecological principles and improved cultural and management practices for field crops.*

2.3.4 *Develop basic ecological principles and improved cultural and management practices for horticultural and specialty crops.*

2.3.5 *Develop basic principles for and improved methods of pollination and honey production.*

2.3.6 *Discover principles for and develop criteria and specifications for improving the efficiency of agricultural production and protection equipment and practices.*

Production research is the essential step through which basic knowledge and germplasm resources become useful on the farm. In the production phases of agriculture, genetically controlled biochemical and biophysical processes are expressed as leaves, flowers, or fruit in the conversion of solar energy, soil, air, and water into food and fiber. The purpose of crop-production research is to identify major cultural problems and limitations and to develop practices that solve or circumvent them. Such research requires

knowledge of the basic plant processes that are responsible for the growth and development of plants, as well as close coordination among plant breeders, engineers, entomologist, pathologists, soil scientists, and others. This research is concerned with all aspects of production—from the planting of viable seeds to seedling establishment, plant flowering, and harvesting of vegetative portions, seed, or other crop products. Both quantity and quality are important. For some crops, pollination by bees or other insects is essential, and honey is a valuable byproduct of pollination.

Production research must deal with many variables, most of which interact. Some of the major variables are tillage practices, crop varieties, row widths and planting density, time of planting, fertilization and irrigation (both timing and amount), pest-control methods and practices, time and methods of harvesting or grazing, and—most influential of all—the weather. Many cultural practices are used even for a single crop in the United States, and finding the best one(s) is an enormous task. Quality, especially in food crops, is often as important as is quantity of production. The payoffs, however, are high. Cash receipts totaled nearly $70 billion for the crops produced in 1980, despite losses of about $20 billion caused by one of the worst droughts we ever experienced. However, losses would have been much greater without the production technologies and superior germplasm developed through research.

To meet projected demands for crops and to reduce the costs of producing them, we will need to expand production research. As new crop varieties and hybrids become available, the best combination of practices must be found. A particular opportunity for the southern half of the United States is the use of double cropping to take advantage of the long growing season and high rainfall in the Southeast. Major research needs are the development of cultural practices for safe use of erosive and other marginal lands and the restoration of the 60 percent of our rangelands that is in poor to fair condition. In that research, consideration must be given to many kinds of equipment—planters, cultivators, sprayers, fertilizer spreaders, harvesters, and primary tillage machinery. As farming becomes more complex and precise, so do the machinery and practices for delivering needed inputs at the proper times, rates, and combinations. Researchers must help determine design criteria and specifications so manufacturers can produce better equipment for agricultural production and protection, and farmers can reduce their production costs.

Approach 2.4 **Discover Principles and Develop Improved Methods for Reducing Crop Losses Caused by Weeds, Diseases, Insects, Nematodes, and Other Pests.**

Approach Elements

2.4.1 *Develop knowledge of growth, development, and behavioral and population processes of insects as a basis for discovering control principles.*

2.4.2 *Develop knowledge of etiology, epidemiology, and pathogenicity of plant pathogens as a basis for discovering control principles.*

2.4.3 *Develop knowledge of growth, development, and behavioral processes of nematodes as a basis for providing control technology.*

2.4.4 *Provide technology for protecting range, pasture, forage, and turf from losses caused by insects, nematodes, pathogens, and other pests.*

2.4.5 *Develop principles for protecting field and horticultural crops from losses caused by insects, nematodes, and pathogens.*

2.4.6 *Develop knowledge of the basic biology of weeds determining their vulnerability to control.*

2.4.7 *Develop control technology for reducing losses caused by weeds in forage crops, pastures, rangelands, turf, aquatic environments, and noncroplands.*

2.4.8 *Develop control technology for reducing losses caused by weeds in field and horticultural crops.*

2.4.9 *Develop fundamental principles of biological control for pests of crop plants.*

2.4.10 *Discover principles and develop agricultural chemical technology for reducing crop losses and for modifying plant growth for improved crop protection and production.*

2.4.11 *Develop fundamental principles for the control of vertebrate pests.*

Crop losses caused by pests of various kinds are estimated at $30 to $40 billion per year, plus another $10 billion spent in efforts to control them. Roughly 10 percent of those pests are perennial problems of economic significance. Experience suggests that the difficulty of protecting crops increases as production practices become more sophisticated and intensive. An example is the serious weed problem now appearing in minimum-tillage and "no-till" systems. We can expect many kinds of pest problems in double-cropping systems, especially those coupled with tillage methods that leave crop residues on the soil surface. Unless we can markedly improve our understanding of the growth, development, and behavior of pests, opportunities for major improvements in crop productivity and erosion control will be severely limited.

The magnitude and complexity of the task facing researchers and action agencies are illustrated by the large numbers of pest species of economic significance. Consider, also, that some pests attack several crops—or one crop may be attacked by several pests—and that the soils and weather, along with fertilization and other cultural practices that control the growth and interactions of the pests and crops, have many variables. Those variables and the ability of pests to adapt rapidly to changes in their environment explain the short utility—possibly only 10 years or less—of control practices or resistant crops. The research task is not only complex, but also apparently never ending.

To gain some control over pests, we need research programs with the highest degree of innovation and sophistication. The programs must extend from the most basic studies at the cellular and molecular levels to large-scale pilot studies in the field. We must find better ways to follow the life cycles and migration patterns of pests, to mathematically

describe their growth and development as functions of temperature and other key variables, and to monitor and assess population increases and damages. Then we can develop improved technologies—both chemical and biological—that will interrupt the growth of pests at strategic times and prevent their buildup to economically damaging levels. Such technologies must be developed for each crop and each pest. No one practice or management system can suffice, although IPM systems hold great promise for some combinations of crops and pests.

Vertebrate predation causes large losses to agricultural products—both before and after harvest—in the United States and abroad. Continued research effort must address those losses. Coyotes and birds—along with rats and many other rodents—soil, kill, consume, or devalue products or increase operating costs at many levels of the agricultural production, distribution, and marketing systems. Efficient, safe, economic controls must be devised. Through research, new technology will be made available.

Scientists think that research has a high probability of success, not only for cutting crop losses, but also for reducing control costs and for preventing potentially adverse side effects from pesticides. Certainly the potential benefits are great—$11 billion annually for improved weed-control measures alone. Research on the control of crop pests also has significant indirect benefits in protecting people and animals from insects and the diseases they carry, from allergenic and toxic plants, and from other pests. Also important is the support that the research provides for the action programs of several agencies, most notably the Animal and Plant Health Inspection Service (APHIS) of USDA.

Approach 2.5 **Develop Improved Methods for Integrating the Crop- and Pest-Management Practices Needed for Higher and More Stable Levels of Crop Production.**

Approach Elements

2.5.1 *Develop the means for assessing crop conditions, and identify the factors that limit yields of major crop commodities.*

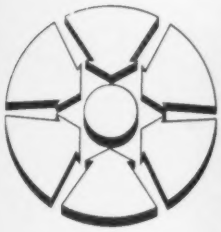
2.5.2 *Develop growth and management models for optimum production of crop commodities.*

Crop production is one of our most complicated activities. Most industrial commodities are produced in factories with controls and checks at every step. In sharp contrast are the farms with no control over such main variables of production as sunlight, rainfall, temperature, and wind and only limited control over many of the pests that limit production. Knowledge is the key to dealing with such uncertainty and risk. With precise knowledge of the way crops and pests grow and interact with each other and the environment, we can identify limiting factors. We can also build predictive models to help farmers respond to pests or adverse weather with management practices that will conserve inputs and maximize farm profits.

In this approach, the data from the basic and applied research described in the other approaches in objective 2 are incorporated into subsystems and simulation models that are useful to both researchers and producers. Those subsystems also serve as components of the complete agricultural systems described in objective 6. As one example of the need for such systems research, no one knows why average farm yields of several crops peaked years ago or has identified the barriers that limit further increases. To find the reasons and identify the barriers, we need to measure and analyze the relationships of crops and pests to each other and to environmental factors such as light intensity, humidity, temperature, soil fertility, and soil moisture. As one author stated recently, "Only to the extent that we can describe productivity in terms of the mechanisms that control photosynthesis and growth can we bring productivity improvement out of the dark ages of pure empericism."

Simple, quantitative models that incorporate data from broad agricultural and economic sources are becoming powerful farm-management tools for optimizing production. They can be used to determine optimum rates of fertilization, times for spraying insects, and times for and amount of irrigation, as well as to guide managers in other critical decisions. Models also can be used to help identify research opportunities and critical field experiments that are needed for each combination of pest and crop. The key in this approach is the integration of our knowledge of crop plants and of the pests that limit their productivity. New and improved IPM systems are especially needed for optimum control of pests of all the major crops.

Objective 3
Develop the Means for Increasing the Productivity of Animals and the Quality of Animal Products



The availability of a vast array of foods from animals helps make Americans among the best fed people people in the world. Because animals convert plant materials that humans cannot digest to foods of high nutritional quality and monetary value, they are an important link in the food chain. Opinions differ among scientists about the proportion of our diet that should come from animals sources. Of diets consumed by Americans, however, more than 45 percent (by weight) is derived from animals. Animal products supply two-thirds of the protein, one-third of the energy, four-fifths of the calcium, and nearly two-thirds of the phosphorus in the American diet. Foods from animals also are major sources of vitamin B_{12} and important sources of iron, vitamin A, thiamine, riboflavin, vitamin B_6, and other essential minerals, micronutrients, and vitamins. As developing countries improve their economies and as U.S. citizens move up the economic ladder, their demand for foods from animals tends to increase. Animals also provide leather, wool, feathers, horn, bone, and biological products, such as the hormone insulin, that are important to human health. Animals are important models for conducting research related to the improvement of human health, are still used in some areas for transportation and power, and provide pleasure for many people. Beef and dairy cattle, swine, sheep, goats, poultry, horses, fish, rabbits, fur-bearing animals, laboratory animals, some beneficial and harmful insects, and predators and other specialized animals that are related to agriculture must be considered in our research strategy. Aquaculture (fish farming) is an emerging area of opportunity for increased productivity and more efficient use of land and water resources.

Animal production is important to the U.S. economy and generates about 52 percent ($70 billion in 1980) of the total farm income. Grazing animals are important in the use and maintenance of the natural resources in our ranges, pastures, and forests. They con-

tribute to resource conservation by producing food from land that is not made vulnerable to erosion by tillage and from land in terrain that is unsuitable for crop production.

Losses from diseases, parasites, pests, and biological and management inefficiencies cause losses to the animal-production industry and to consumers that amount to billions of dollars annually. Research must generate the necessary knowledge and technology for reducing those losses and for supporting action and regulatory agencies of the USDA and other Federal departments in carrying out their responsibilities. Through a combination of research, development, and education, the efficiency of many phases of animal production has increased substantially in the last 20 years. However, as described for crop production, we have reached the limits in many instances, and further progress requires research ranging from fundamental studies of intricate life processes to the development of totally new ways to increase efficiency and productivity. Inadequate basic knowledge is the major limiting factor in improving the efficiency with which we produce and utilize foods and other products from animals. In a conference in May 1980, more than 200 leading scientists, producers, industrialists, consumers, and experts in human nutrition and medicine identified research needs that, if satisfied, would enable agriculture to effectively and efficiently meet future demands for animal products. The approaches and elements listed below are consistent with the priorities identified at that conference.

Approach 3.1 **Increase the Genetic Capacity of Animals for Production.**

Approach Elements

3.1.1 *Devise optimum selection and mating procedures for obtaining high levels of animal performance and improved product quality.*

3.1.2 *Devise procedures for selectively manipulating genetic material to improve desired characteristics.*

3.1.3 *Determine genetic variation in biochemical, physiological, and behavioral traits of animals, and devise ways for using the information to accelerate genetic improvement.*

3.1.4 *Improve genetic resistance of animals to diseases and internal and external parasites.*

The productivity of farm and range animals is shaped by both their genetic makeup and their environment. Much of the improvement in animal productivity in recent decades has resulted from increased genetic capacity for synthesis of meat, milk, eggs, wool, and other animal products. To genetically improve animals, breeders must identify animals that are genetically superior for given environments. The long gestation, slow rate of maturation, and low prolificacy of large farm animals lengthen the time required for evaluating animal performance. To accelerate progress and reduce production costs, we must establish procedures for identifying animals that are genetically superior without waiting for their full development. Such procedures will require new methods for reliably estimating both the genetic merit of individual animals and the performance of specific matings for the development of alternative systems for selecting and mating animals.

Genetic engineering research could produce techniques for identifying and transferring genetic material between animals and between animals and bacteria. Possibly through cloning and related technologies, genetic copies of superior animals could be produced. Other long-term research is needed on genetic manipulation to produce animals that are resistant to diseases and parasites. If we could identify the genes and their products that make certain animals susceptible or resistant to parasites and diseases, resistance might be bred into livestock

We must determine, in animals, the effects of genetic variations on hormones, enzymes, and other biochemical regulators of performance and of economically important traits. The genetic control of immune responses, behavior, and resistance to diseases, parasites, pests, and other stresses also must be studied. Of particular importance are genetic influences on metabolism that might be used to regulate the types and proportions of fats, proteins, vitamins, and minerals in animals and in foods produced from them.

Approach 3.2 **Improve the Efficiency of Reproduction and Reproduction-Related Biological Processes.**

Approach Elements

3.2.1 *Increase the number of offspring reared per male and female maintained.*

3.2.2 *Increase efficiency of germ cell and embryo production, transfer, and storage and of techniques for producing more offspring of superior quality.*

3.2.3 *Increase efficiency and persistence of lactation and egg production.*

The failure of animals to reproduce consistently and prolifically is one of the most costly and production-limiting problems facing our livestock industries. Annual losses from low performance are estimated at $10 to $14 billion, or 14 to 20 percent of the total income from U.S. animal agriculture. The reproductive rate of most animals is 80 percent. A 10-percent increase in reproductive rate would increase efficiency by 6 percent, which alone would save producers about $4 billion annually.

Reproductive efficiency might be improved by increasing twinning in beef cattle, shortening the calving interval in dairy cattle, increasing embryonic survival in swine, and increasing the frequency of multiple births in sheep. We should develop and improve procedures for controlling the timing of ovulation and for synchronizing estrus. Nuclear transfer, semen preservation and predetermination for sex, *in vitro* fertilization, and mechanisms for controlling the fertility characteristics of individual animals also should be emphasized. We must undertake basic biological research on development of the technology for freezing, storing, and then thawing embryos for use in improved technologies for transferring embryos. The answers gained through basic and applied research in all of those areas, and their subsequent use by producers, could significantly advance the genetic and productive capabilities of livestock.

We need a better understanding of the endocrine and neuroendocrine mechanisms that regulate feed-energy conversion and milk-secretion processes and of the hormonal and cellular mechanisms that control milk synthesis. To improve the productive capacity of

turkeys and other poultry, we need similar studies to determine the mechanisms that regulate egg synthesis. Studies are also needed on turkey-semen preservation, sperm transport, ovulation, and oviposition and on their relationship to egg hatchability.

A strong, integrated research program to improve the reproductive efficiency of animals is essential for maintaining progress in the efficient production of meat, milk, eggs, and other animal products.

Approach 3.3 **Improve Animal Nutrition and Feed Efficiency To Increase Productivity and Product Quality.**

Approach Elements

3.3.1 *Remove nutrient limitations to production.*

3.3.2 *Reduce losses and inefficiencies in nutrient use, and explore alternative sources of nutrients.*

3.3.3 *Devise nutritional and physiological means for modifying the rate of synthesis and the composition of animal products.*

Because feeds represent 40 to 50 percent of the total costs in animal production, efficient feed utilization is essential for profitable production of meat, milk, and eggs. We must improve our understanding of the factors that affect nutrient needs; the digestion, absorption, and assimilation of nutrients; and the synthesis of animal products. Any gains made in improving feed utilization by animals and in lowering feed costs will improve the economic viability of livestock producers and lower the cost, to consumers, of foods from animals.

Only through basic research can we understand the metabolic processes through which animals convert feed to meat, milk, and eggs and, through that understanding, develop technology that will enable animal producers to improve the efficiency of the metabolic processes that control the composition of animal products. Although general nutrient needs of animals are known, we now need to know their specific nutrient needs, at various stages of their life cycles, for producing meat, milk, eggs, and wool of the highest quality and in the greatest quantity. As we genetically improve the productivity of animals on farms and rangelands, we must reconsider their nutrient requirements. Maximum animal performance depends upon high feed intake, and we must define the physiological factors that control the appetite of animals in different stages of growth and under different environmental conditions. The effects, on feed intake, of (1) composition and physical state of the feed and (2) physiological factors should be clarified. By understanding the nutritional needs of animals at all times, we can devise improved ways for managing soils, crops, and livestock to meet those needs.

Microbes in the digestive tracts of animals ferment and grow on feedstuffs consumed by the animals and, in ruminants, are responsible for cellulose digestion. Feedstuffs must, therefore, be designed to nourish both the host animal and the desirable microorganisms in the digestive tract. Because cellulose is a major component of many feeds,

we need to understand the factors that limit digestion of cellulose and hemicellulose and the conditions that favor maximum benefits from the micro-organisms in the gastrointestinal tract. Additional research is also needed on chemical and biological procedures that will free, for use by ruminants, extra energy from the lignocellulosic substances in low-quality feeds, forages, and plant residues.

Approach 3.4

Develop Ways To Prevent or Control Losses From Diseases, Parasites, and Toxicants and Other Substances That Limit Animal Performance and Reduce the Quality of Animal Products.

Approach Elements

3.4.1 *Improve methods for diagnosing and identifying agents that cause losses, and improve methods for assessing those losses.*

3.4.2 *Establish the roles of environmental stresses and nutrition in losses from diseases and parasites.*

3.4.3 *Characterize the mechanisms by which animals become infected and are affected by diseases and parasites.*

3.4.4 *Devise new and improved methods for preventing or reducing death, morbidity, and other losses from diseases and parasites.*

3.4.5 *Prevent, control, or eliminate losses from natural or synthetic substances to which animals may be exposed.*

Throughout the world, diseases, internal parasites, and toxicants cause major losses and are important causes of low animal productivity. In the United States, they cost livestock producers, and subsequently consumers, an estimated 20 percent of the farm income from livestock and poultry products, or about $14 billion per year. Losses from diseases, internal parasites, and toxicants include death, restricted growth, reproductive inefficiencies, and veterinary costs. Other losses are from "production diseases," which often produce no recognizable clinical signs of disease but do lower productive efficiency. As a class, they are complex epidemiologically and have infectious, toxic, genetic, metabolic, and nutritional etiologies, or combinations thereof. They generally result from several etiological factors that act in concert with environmental and production factors. This class of diseases includes infectious complexes, reproductive disorders, metabolic imbalances, toxicoses, digestive system disorders, nutritional disorders, stress-related syndromes, parasite and insect infestations, and combinations of two or more thereof.

Research is needed to find new and improved methods for identifying losses from diseases, parasites, and toxicants. We need tests for diagnosis of recognized diseases, detection of inapparent carriers, identification of new diseases or sources of loss, and assessment of losses attributable to individual diseases. Rapid diagnosis is critical for treating sick animals early, preventing exposure of healthy animals, and safely moving animals from one farm to another. The identification of new diseases should help control losses from "production diseases" and from reproductive diseases, which often are never identified because the disease-causing agent disappears before its effects are seen.

Research is needed to define the effects, on health, of stresses associated with the environment, disease, and nutrition. We should study the factors that influence infection by disease, including the effects of hormones on the immune system and the response of animals to vaccination. We also should study, at the cellular level, the interactions of disease agents and the control of interactions by hormones and genes. Stresses and nutrition also affect losses caused by parasites, but those interactions are poorly understood. Even more poorly understood are the mechanisms by which diseases and parasites are transmitted, infect animals, and adversely affect their health.

Recombinant DNA technology is expected to revolutionize the production of vaccines and other biological materials that are needed to prevent disease or promote growth. Advantages of the technology are safety of the products and the ease with which abundant supplies of vaccines and materials can be produced. We should thoroughly explore the potential of recombinant DNA technology for producing vaccines and products that stimulate the natural immunity of animals.

Research is needed to determine the toxic, metabolic, and subclinical effects of agricultural chemicals and poisonous plants on livestock and the relationships of those chemicals and plants to diseases and efficiency of production. In that research the risks of undesirable residues in meat, milk, and eggs should be assessed. Further research is needed on medicinals, feed-grade chemicals, antimicrobials, and drugs for prevention and control of disease and/or for increasing efficiency of animal production. Research also is needed to identify plants that may be harmful to animals; to determine their toxic components, mode of action, and possible hazards to public health; and to find means for preventing losses of livestock from exposure to such plants.

Approach 3.5 **Develop Means for Controlling Insects, Ticks, and Mites That Affect Animals and Man.**

Approach Elements

3.5.1 *Improve methods of detecting infestations and assessing losses.*

3.5.2 *Examine mechanisms by which insects, ticks, and mites cause harmful effects.*

3.5.3 *Devise new and improved methods for reducing losses from insects, ticks, and mites that affect animals and man.*

3.5.4 *Integrate control technologies into systems approaches for managing insects, ticks, and mites that affect animals and man.*

3.5.5 *Develop means for protecting humans from insects and insect-borne diseases.*

'In the United States, insects, ticks, and mites that affect livestock and poultry cause annual losses estimated at more than $3 billion. Insects, ticks, and mites also directly affect people by impairing their health and productivity through annoyance, debilitation, and disease transmission. The estimated annual cost of those pests and disease vectors to civilian and military populations of the United States exceeds $1 billion.

A balanced program of basic and applied research should provide the knowledge and technologies that are needed to alleviate those losses. Methods of detecting infestations of insects, ticks, and mites must be improved, and thresholds of economic importance must be determined for species that affect man and animals. Early, accurate detection of infestations and assessment of losses are essential to timely application of control measures. Basic research on the biology and ecology of specific pests is needed to provide the knowledge for designing effective controls. For development of vaccines, we must understand the role of immune systems in the natural and acquired resistance of animals and identify the genetic products and immune-response genes that are responsible.

New and improved methods of reducing losses should be emphasized in research on the chemical control of insects, ticks, and mites that affect man and animals. Genetic methods of altering the pests, themselves, also must be devised through such mechanisms as hybrid sterility, male sterilization, cytoplasmic incompatibility, chromosomal translocations, compound chromosomes, and other genetic anomalies. Special attention is needed to discover and develop effective bilogical control agents, such as pathogens, parasites, and predators. Possibly in studies of animal facilities, water management, or manure disposal, we could develop improved techniques for control. Basic research may reveal either physiological systems that can be interrupted to alter pest behavior or ways for producing new, physiologically active chemicals to control pests. Applied research will be used to combine chemical control, host immunity, genetic control, biological control, cultural control, and novel approaches into integrated systems for the management of insect, tick, and mite populations so they can be maintained below thresholds of economic importance.

A strong research program that provides the means for controlling insects, ticks, and mites that affect animals and man should enable farmers, with the help of such agencies as APHIS, to reduce animal production losses by 15 percent (national total of $450 million per year). It should also provide the means, particularly through the Departments of Agriculture, Defense, and Health and Human Services for reducing direct losses to human health and productivity by 20 percent, or $200 million per year. Potential savings in human life, health, productivity, and well-being are inestimable.

Approach 3.6

Devise Means for Improving and Integrating Procedures and Facilities for Production and Transport of Animals To Increase Productivity, Reduce Costs, and Minimize Stresses.

Approach Elements

3.6.1 *Assess environmental impacts and shelter needs for farm animals.*

3.6.2 *Develop facilities and equipment for feedstuff storage, processing, and distribution.*

3.6.3 *Develop facilities and equipment for improving animal performance and labor efficiency in production systems.*

3.6.4 *Develop improved facilities and equipment for handling and transporting animals.*

3.6.5 *Develop systems for managing and using manure efficiently as a resource.*

3.6.6 *Devise integrated management practices for maximizing animal productivity and product quality, while minimizing stress.*

3.6.7 *Evaluate, for optimum use of resources, management programs that integrate all productivity elements under various environmental conditions.*

As labor and other costs have risen, animal producers have improved efficiency through better management and the use of labor-saving equipment, and the average size of animal-production units has increased. Millions of dollars are invested annually in animal-production facilities and equipment. For reduction of those costs, research is needed to provide engineering and management technology for modern livestock and poultry farms and to integrate available technologies into efficient systems.

Environmental factors interact to influence animal performance. We should conduct research to define the criteria that are needed for evaluating environmental requirements for optimum animal performance and for designing more effective facilities and equipment to protect animals from weather, insects, diseases, and other destructive influences. Valid models must be developed for assessing environmental impacts on animals and for selecting alternative shelters and handling procedures and equipment for farms, feedlots, and ranches.

We must find ways to increase the efficiency and accuracy of feed preparation, delivery, and utilization by improving the facilities for storage and handling and the controls for blending and dispensing. Automated procedures for collection and analysis of information should be developed that will facilitate daily management decisions on breeding, feeding, housing, and marketing and on control of diseases, parasites, and pests. We must find ways to reduce the losses of animals and animal products during handling and shipping. Another area of opportunity is finding ways to efficiently use the nutrients and energy contained in animal wastes.

Management systems for optimum use of resources must be evaluated for most efficient production of beef and dairy cattle, swine, sheep, poultry, fish, and other economically important species. All aspects of farm-animal production must be integrated into total management systems that provide optimum care for animals, reduce stresses, and improve efficiency and product quality. Integration will involve development and evaluation of computer simulation models of alternative total management systems for the optimum use of biological, physical, and economic resources under the widely different conditions across the United States. Reducing losses of animals to predators is a critical need in some phases of livestock production.

Objective 4
Develop the Means for Achieving Maximum Use of Agricultural Products for Domestic Markets and Export

Public benefit from agricultural business depends upon delivery of a dependable supply of food and other agricultural products to consumers through an effective and efficient marketing system and upon an adequate return to farmers who produce the raw products. The economic incentive for engaging in agriculture—the planting of crops and the breeding of animals—lies in the increment between the costs of a farmer's total investment and his total return. That increment, profit, depends heavily upon the marketing system. A myriad of firms, organizations, and individuals pack, process, handle, transport, store, and distribute farm products. In fact, marketing costs accounted for more than two-thirds ($183 billion) of the money spent for domestically produced farm foods in 1980.

The difference between the price received by farmers and the price paid by consumers—the "farm-retail price spread"—has been increasing in recent years and undoubtedly reflects the rising costs of capital, labor, services, and all other inputs that are added, during marketing, to the costs of production. Some added costs do increase value by enhancing the safety, nutrient content, or convenience of food items or the utility of nonfood items, but others reflect the costs of advertising and extravagant packaging. The increasing farm-retail price spread also could indicate declining efficiency in the marketing system. We must pursue research that facilitates the profitable marketing of both the raw agricultural materials and the processed products manufactured from them.

No products of American business are more important to the Nation's economic health than are the exports that earn foreign credits. Among our total exports, agricultural products predominate and indirectly help pay for the oil and manufactured products that we import. Maintaining and enhancing the value of those exports could help achieve op-

timum use of our agricultural product. We should also develop new crops and products for export. We must develop technologies, for all phases of posthar[illegible] treatment and for transport, that will ensure delivery of high-quality products to foreign markets. New scientific information about the essential characteristics of agricultural products for export and about the technologies for shipping those products should not only help other Government agencies in establishing standards that meet export goals, but also help industries in developing products and technologies that meet the needs of foreign buyers.

Most agricultural products must be processed or modified in some way before they are marketed and used by consumers. Modifications can range from subtle improvements—for example, removal of green color from oranges— in products that are consumed as harvested to separation into components for direct use or for use in formulations, mixtures, or unique products. The changes may either improve the nutritional, sensory, or functional characteristics of products or improve their safety, durability, convenience, and utility. Conversions of agricultural wastes and residues—and even new crops—into alternative fuels and petrochemical substitutes are examples of processing products into nonfood items. Traditional processing operations include physical, chemical, and biochemical methods. Recent advances in biotechnology open the door for creating totally new kinds of food and nonfood items from agricultural raw materials and for improving the utility of traditional items.

To develop advanced technologies, scientists must first acquire basic knowledge of the chemical and physiological processes and properties of individual commodities and potentially valuable new crops. Certain traits can be used as indexes for objectively and automatically classifying, sorting, and segregating commodities according to their quality, safety, and market value. Those indexes could also be useful as criteria for use by geneticists and breeders in developing genotypes with improved quality.

We often need basic data for improving technologies for preserving and storing agricultural products. The perishability of raw agricultural commodities is a major challenge to the marketing sector and to research. Perishability is manifested in different ways and to different degrees. Each commodity requires specific methods of protection during handling, storing, processing, and retailing to prevent deterioration, loss, or contamination that could be hazardous to consumers. Major factors that influence perishability are damage—from insects, microbes, and physical abuse—and chemical and metabolic breakdown. Those factors cause annual losses of food, alone, estimated at $31 billion. In addition, all the labor, energy, and other resources expended during production and marketing, up to the time of loss, are wasted. To meet future needs for food and fiber at affordable prices, we must find more effective ways to prevent losses.

Scientists also should develop means for enhancing the total market value of the agricultural product. With new technologies, we should be able to increase the marketable portion of the agricultural output, enhance desirable traits, and decrease or eliminate undesirable traits in natural or processed products of plants and animals. We may be able to find new crops or to develop totally new products.

Scientists also are challenged to develop means for improving the overall efficiency of the entire system of harvesting, processing, transporting, and marketing. Inefficiencies in that system could offset potential gains in yield and product quality. We need to identify the costs for labor, time, energy, water, and other inputs that could be reduced and the steps and procedures that could either be eliminated or combined to shorten and simplify the whole marketing process. We need studies of the methods, facilities, and equipment used to handle, process, grade, package, and ship specific commodities and products. In those studies, we should examine the system from the farm through assembly points, processing plants, storage, and delivery. In the analysis of the marketing system, use of computerized information systems and models will help us to identify inefficient steps that should be modified or eliminated.

Approach 4.1 **Develop Means for Enhancing the Inherent Properties and Uses of Agricultural Materials.**

Approach Elements

4.1.1 *Characterize the basic, physical, chemical, and aesthetic properties of plant and animal materials that enhance their usefulness.*

4.1.2 *Identify the biological and biochemical mechanisms, in plants and animals, that affect properties of agricultural materials.*

4.1.3 *Devise means for regulating and controlling the biological processes that enhance usefulness.*

4.1.4 *Devise concepts for innovative and improved processes and products.*

For maximum value, farm products must meet market demands for quality and utility. However, we often cannot measure either trait directly and must characterize its associated properties—such as flavor, color, texture, and strength. We need new chemical, mechanical, or electronic methods for evaluating quality and utility objectively.

The basic biological and biochemical processes that function in the cells of growing plants and animals influence the market value of farm products. Those processes respond to nutrients, environment, and cultural practices during production. We must identify the basic processes that are responsible for producing desirable and undesirable properties in the products of plant and animal origin. For effective use of the knowledge of basic processes, we must devise means for stimulating the processes that produce desirable properties in farm products and for suppressing those that produce undesirable properties.

For some commodities, we have developed multiple uses. From corn—which is used primarily as feed for livestock—we manufacture a myriad of breakfast foods, oils, sweeteners, starch, alcohol, and many other products. Processing also enhances the utility of other crops, of which potatoes are a notable example. Processes for flame-retardation and wash-and-wear characteristics in cotton and woolen goods are other examples. We must develop new uses for farm products and new methods for enhancing their value.

We must be innovative in research related to animal products. New concepts of nutrition and modification of dietary habits could affect the markets for products of animal origin. Scientists have successfully produced lean hogs, are reducing the sodium content of processed meats, and have experimentally modified the constituents of milk and eggs. With the basic knowledge of the biological processes by which animals metabolize nutrients into meat and other animal products, and with the means for controlling those processes, scientists might be able to improve the nutritional quality and marketability of products of animal origin. Foreign markets, especially industrialized nations such as Japan, offer attractive possibilities for our products from animals. By improving the technology for maintaining—in meat and meat products—the high quality necessary for expanding foreign markets, scientists can contribute to our Nation's economy. Exporting finished products not only improves our balance of payments, but also creates more jobs at home.

Approach 4.2

Develop the Means for Meeting Foreign and Domestic User and Regulatory Requirements Relating to Toxic Factors in Food, Feed, and Other Agricultural Products.

Approach Elements

4.2.1 *Identify and, when necessary, develop the means for removing intrinsic toxic factors of practical significance.*

4.2.2 *Identify and, when necessary, develop the means for removing extrinsic toxic factors of practical significance.*

Safety is important throughout the agricultural system, but it is essential in food. Farm products containing recognized hazards cannot be sold. As a result, producers lose income and the public loses food. Awareness of the importance of safe, highly nutritious foods and safe workplaces is increasing. Throughout production, processing, and distribution, the safety of the food supply is challenged by natural constituents such as enzyme inhibitors, hemagglutinins, goitrogens, and saponins. Processing, cooking, dilution, digestion, and detoxification by metabolism protect us from many natural toxins, but we need information for setting reasonable threshold levels in food and we need to find ways to prevent or control excessive amount.

We could control or eliminate some natural toxins in plant materials that we eat or feed to animals by developing varieties of plants that do not produce toxins. By studying the biochemical processes of cells, we should be able to manipulate the bioregulators of plant metabolism to minimize toxin production. Much of such work will be on crops for livestock feed.

During processing, many compounds—such as salt and sugar—are added to foods. Most traditional food additives are assumed to be safe, but even those can be harmful in excess. Some potentially harmful compounds, such as those produced by browning reactions, can form during processing. Others may result from contamination or may be residues of agrichemicals, antibiotics, or hormones. We must increase our understanding of the toxicology of all potentially harmful compounds and develop methods for detecting and measuring them and their reaction products during processing and storage.

The gastrointestinal illness called "food poisoning" affects as many as 20 million people annually in the United States. Outbreaks continue because (1) producers and consumers are ill informed and do not take known precautions; (2) bacteria, fungi, and viruses that can cause food poisoning are widespread; and (3) we lack basic knowledge about the factors that affect the survival of the organisms and the synthesis of their toxins. To locate and possibly eliminate sources of contamination, we should improve methods for isolating, identifying, and enumerating bacteria, fungi, and viruses that are associated with food. We also should identify—for microbes—the genetic, ecological (physical and chemical), and nutritional factors that interact in foods to favor the development of food poisoning. With that information, we should be able to develop methods that will prevent microbes from growing or forming toxins, or both.

In some years, under some conditions, certain species of fungi invade and produce mycotoxins in such crops as corn, wheat, cotton, peanuts, and tree nuts. Mycotoxins can be ingested with feed and appear in milk and meat. The levels at which mycotoxins become hazardous in food or feed vary among specific toxins produced by different fungi. The Food and Drug Administration of the Department of Health and Human Services has established tolerances for one group of mycotoxins—aflatoxins—in some crops. Using ARS methods, the peanut industry identifies and segregates contaminated peanuts from those that are used directly in foods. For crops that are susceptible to toxin-producing fungi, we must develop sensitive, rapid, and inexpensive methods for sampling and analysis. In assessing the safety of agricultural products, we must identify hazardous etiological agents and evaluate the levels of the hazards to determine whether they have practical importance. For any that are important, we must explore methods for preventing, detoxifying, processing, and grading to eliminate or control the hazard.

Workers who handle farm products can be exposed to conditions that could be hazardous. Byssinosis, for example, is a respiratory ailment that apparently is associated with exposure to cotton dust in the workplace. That association threatens the U.S. cotton industry, and we need scientists in several disciplines to identify the causative factors. Then—by studying all phases of cotton production and processing—they must either try to find cost-effective treatments for cotton or develop handling procedures that would eliminate the problem.

Approach 4.3

Develop Means for Reducing or Eliminating Postharvest Losses Caused by Pests, Spoilage, and Physical and Environmental Damage.

Approach Elements

4.3.1 *Develop improved methods for controlling losses caused by insect pests.*

4.3.2 *Develop improved methods for controlling losses caused by micro-organisms.*

4.3.3 *Develop improved methods for controlling losses caused by internal chemical and biological mechanisms.*

4.3.4 *Develop improved methods for controlling losses caused by physical forces.*

All agricultural commodities are subject to losses during all stages of the marketing system. The extent of total postharvest losses of food worldwide is not known, but for cereal grains, the worldwide loss probably ranges from 10 to 20 percent. The Food and Agricultural Organization estimated that a 10-percent loss would be equivalent to one-half pound of cereal per day for each of 400 million people. The losses of perishable fruits and vegetables are undoubtedly higher. In the United States, about 20 percent of all food produced each year is lost—a loss that amounts to an estimated 137 million tons valued at $5 billion. Estimates of losses caused by pests, alone, range from 3 to more than 10 percent. A 5-percent loss at 1980 retail prices would amount to $14 billion.

Total losses include those of quality and quantity. Both types of loss can occur during all stages—storage, processing, handling, and distribution—of the marketing system. Losses are caused by physical damage, ineffective procedures, and chemical and biological deterioration—but most commonly by the activities of insects and micro-organisms. Often, losses of a given commodity are caused by the interactions among several causes. Some micro-organisms, for example, do not attack sound fruits but do enter wounds inflicted by insects or by rough handling. Thus, the measures devised for controlling losses also interact and cannot be isolated in either theory or practice.

Refrigeration is the critical factor in preserving our perishable agricultural products and in supporting our modern life style. Low temperatures prevent losses that are caused by either pathogens or biological deterioration and also protect against some insects. Scientists have refined procedures for manipulating atmospheres as supplements to refrigeration, but the optimum conditions—of temperature, humidity, and atmosphere—that are regulated for preservation of perishables must be defined for each commodity. We also must explore irradiation as an alternative means of preserving foods for long periods and for use where refrigeration is not available. Foods in sealed containers that are given sterilizing doses of radiation can be stored at room temperature for years without spoiling, and they are not radioactive.

Many of our present methods for controlling insects and other pests that infest commodities during marketing rely upon chemicals whose effectiveness is declining as resistant strains of pests develop and whose safety is being questioned. We must develop a new generation of pesticides that are nontoxic and persistent. Biological controls, and even an insecticide produced by a bacillus, are available for use in the field. Scientists must search natural sources for repellents and pesticides that would be safe for use on commodities during marketing.

To develop new methods for controlling postharvest losses of agricultural products, we need basic knowledge about the biology and ecology of insects and micro-organisms, about the interactions among them, and about their interactions with their hosts and their environments. We must study the basic processes by which the cells and tissues of biological materials deteriorate—even under optimum conditions. Conversely, we need to understand the mechanisms whereby such materials resist deterioration. To devise procedures for minimizing losses from physical damage, we need to understand the biological nature of physical injuries.

Genetic manipulation offers a promising, long-range opportunity for the development of nonchemical methods for controlling losses of agricultural products. We know that some species, and even some strains of species, are more susceptible to attack by pathogens and insects and to physical damage than are others. In cooperation with geneticists, who enhance production by developing resistant strains of plants and animals, scientists in postharvest technology should study commodities, when they are ready for market, for signs of genetic resistance to factors that cause postharvest losses. The introduction—into plants and animals—of genetic material that would either enhance the resistance of their perishable products to attack by insects and pathogens or delay biological deterioration during marketing could be the most effective and least costly means of controlling postharvest losses. Integrated management systems that include all available means for controlling losses hold great promise for increasing the quality and quantity of agricultural products.

Approach 4.4

Develop the Means for Increasing Efficiency of Systems for Processing, Handling, Storing, and Distributing Agricultural Products.

Approach Elements

4.4.1 *Identify system inefficiencies.*

4.4.2 *Devise means for reducing or eliminating inefficiencies.*

4.4.3 *Devise means for efficiently classifying products for exchange in the marketplace.*

4.4.4 *Devise means for meeting domestic and foreign quarantine and other requirements that restrict movement and trade of products.*

A recent assessment of business productivity attributed 67 percent of the growth in both total production and gross product per labor hour to advances in knowledge and technology. Of the approximately 30,000 companies (not counting retail outlets) that process, store, and distribute food, only about 100 have research facilities, and the research of each benefits only the owners and customers of that company. Public research benefits all owners and all customers, but Federal and State support for marketing research declined 19 percent between 1966 and 1970, and the scientific workforce declined 15 percent between 1971 and 1980. During the 1950's, agricultural marketing was second only to agricultural production in terms of industrial productivity, whether measured by output/input indexes or by value added to products. Marketing productivity began to decline in the 1960's and now reflects the escalating costs of labor and all energy-related inputs. Through research, we must find ways to reverse that decline. We must also find ways by which companies that process, store, and distribute agricultural products can reduce costs, still maintain or enhance the quality of those products, and improve their competitive position in foreign markets.

We can start with processing—possibly the most expensive function in the marketing system. Processed foods are the principal items in our diet; more than half our food is processed, and about half our meals are eaten outside the home. The food-processing industry is our fourth largest energy user, and the cost of processing has risen with the

costs of energy and other inputs. To compensate for rising costs, we must both improve the efficiency of present processing methods and develop new, better methods.

In basic engineering studies, we must identify and develop technologies that can reduce or eliminate inefficiencies in processing. For example, we can simulate the processing function in computer models and, by systems analysis, detect the steps with the greatest potential for efficiency improvement. On pilot processing lines, we must determine the effects of each processing step on the nutritional value, yield, and appearance of the final product and then identify the steps in which costly inputs could be reduced. We also should find ways of reducing the escalating cost for disposing of effluents from processing lines. Data from computer models and pilot food-processing lines should be applicable to all early steps in processing that are similar for commercial production of canned, dehydrated, or frozen foods.

We must find new uses for commodities that are underused—or even wasted. Of the 20 billion pounds of agricultural fats and oils produced annually in the United States, 8 billion pounds is unsuitable for food. Despite excesses, we still import certain oils for lubricants, soaps, and detergents and for other specific uses. Inedible fats now are converted to food-grade fatty acids by costly, energy-intensive methods. Enzymatic processing could feasibly enhance the utility of underused agricultural fats and oils. Chemical modification of soybean oil might enable the production of extreme-pressure lubricants—formerly based on sperm oil. We must expand efforts to convert our abundance of agricultural fats and oils into substitutes for petroleum and other imports.

The starch that our crops produce in such abundance has many direct uses. It has been modified chemically into many products, such as "super slurper" for unequaled absorbency and xanthate for removing heavy metals from waste water. Renewable, natural starch polymers can be used in biodegradable plastics, and other derivatives have potential uses in processing rubber and in manufacturing urethane foams. Through basic studies of the chemistry of starch, one of our least expensive agricultural products, we should be able to develop new products with high value and utility.

We could increase the utility or export of many products by finding ways to decrease their cost or to improve their quality and acceptance. Improved methods for tanning hides could help restore the competitive position of the U.S. leather industry and reduce our trade deficit of $2.5 billion for imports of shoes. We should reduce the losses and improve the acceptability of the frozen variety meats that we export (valued at $300 million in 1980). Exports of U.S. citrus fruits are increasing, but we need ways for overcoming foreign restrictions that limit our exports of citrus or other horticultural crops. Scientists must continue to help solve emergency problems—such as the infestation by the Mediterranean fruit fly in California—that affect the marketing of commodities. The most important U.S. exports are grains and oilseeds, and we must develop the new methods needed for inexpensive, rapid sampling and grading so that we can maintain and increase their value and acceptability. The ARS must pursue, with renewed vigor, research that facilitates the profitable marketing of U.S. agricultural products.

Objective 5
Develop the Means for Promoting Optimum Human Health and Well-Being Through Improved Nutrition and Family Resource Management

Nutrition is a key factor in the degree to which we achieve the genetic potentials inherited from our forebears. The potentials include those for growth, reproduction, resistence to disease, longevity, and intellectual development. The great array of foods now available contributes to our unprecedented opportunity to reach those potentials during longer and more productive lives. However, our knowledge of the relationship between our nutrition and the degree to which we achieve our potentials is inadequate. The signs and symptoms of most of the severe nutritional deficiencies are known, but the thresholds of deficiencies that cause mild adverse effects are ill defined. Our inability to specify optimum nutrient intakes for people who are at those ill-defined thresholds of deficiency is a major challenge to research.

Methods for detecting and measuring abnormalities of physiological functions are insensitive and, consequently, the range of function that is considered "normal" has been very wide. New and improved technologies should enable us to refine procedures and techniques for measuring function. Also, our enhanced appreciation that "normal" in the statistical sense does not necessarily mean optimum physiological function for individuals should stimulate our efforts to develop ways for defining "normal" in a physiological sense for each person. We need improved methods for determining whether marginally or mildly deficient diets impair function and for measuring the degree of impairment. Such methods will help us to understand the relationship between nutrient intake and ultimate expressions of our genetic potentials. Future nutrition research, therefore, should be strongly oriented toward defining the effects of mild deficiencies or excesses of nutrients on physiological function and on physical and mental well-being over the whole life span.

57-279 O - 87 - 36

Research on humans must be conducted under carefully controlled conditions so that any sensitive measurements of function that are developed can be applied in a reproducible manner and interpreted properly to discover the relationships between specific nutrients and physiological functions. Those relationships could be studied in groups of people whose suboptimum physiological functions might be related to their nutritional status. Information from such studies could provide the basis for identifying population groups that would benefit the most from programs for nutrition education and intervention. To minimize risk and cost, we routinely study the complexities of nutrition in laboratory animals. However, in the final analysis, findings must be verified in human subjects, and people worldwide could be the ultimate beneficiaries.

Approach 5.1 **Define the Nutrient Requirements of Humans at all Stages of the Life Cycle.**

Approach Elements

5.1.1 *Establish the nutrient requirements of infants, children, and adolescents.*

5.1.2 *Establish the nutrient requirements of pregnant and lactating women.*

5.1.3 *Establish the nutrient requirements of adult humans.*

5.1.4 *Establish the relationship between nutrition and aging.*

Together, the two categories "pregnant or lactating women" and "infants, children, and adolescents" account for about 30 percent of our American population. Common to all individuals in those categories is their need for nutrients to meet the specific demands of growth and development. Nutrients for the fetus, the infant at the breast, the child, and the adolescent must provide for a metabolism that is geared to support the rapid growth of the brain, muscles, bones, and all other tissues and to store energy. Failure to meet those nutritional needs during the periods of rapid growth and development could limit, for a lifetime, both the level of genetic potential reached and the ultimate quality of life. We need research programs that will help us ensure that those nutritional needs are met.

Among middle-aged people, obesity is the most widespread nutritional disorder and may adversely affect the health of 30 percent of the men and 40 percent of the women. People become obese when either their energy intake is too high or their output is too low. With present techniques, however, we cannot determine which factor, or what combination of the two, causes obesity in any given individual. We must discover the dietary factors that affect appetite and explore the consequences of satisfying energy needs with different proportions of the major dietary sources of energy. Through the use of stable-isotope techniques, we must study the metabolism of cabohydrate, fat, and protein in human subjects. The human body contains at least 40 minerals, many of which are essential for function. Only by understanding the biochemical reactions that depend on those minerals as cofactors can we establish optimum intakes. We should define, more specifically, the minimum requirements for known vitamins and determine the effects of megadoses of certain vitamins.

The average American now can expect to live to 73 years of age and, by the year 2000, should expect to live well past 80 years. The significance of nutrition in the aging process can be considered in relation to three observations. First, the efficiency of many physiological functions declines progressively throughout adult life, and nutrition may influence the rate of decline. Second, the etiologies of some chronic diseases and disabilities that are associated with aging are influenced by nutritional factors. Finally, food intake generally diminishes with advancing age, but we have little solid knowledge as a basis for recommending optimum intakes of individual nutrients by older people. We need research programs that address the specific nutritional requirements of the elderly for maintaining their functions.

Approach 5.2

Determine the Nutrient Content of Agricultural Commodities and Processed Foods as Eaten, and Establish the Bioavailability of Their Nutrients.

Approach Elements

5.2.1 *Compile essential data on the nutrient contents of foods as consumed in the United States.*

5.2.2 *Determine bioavailability of nutrients in foods as consumed.*

The establishment of policies and the development of plans for national and international food and nutrition programs require accurate knowledge of nutrient content of food. Since the classic USDA Bulletin No. 28, "The Chemical Composition of American Food Materials," was published in 1896, the Department has published and repeatedly updated a series of food-composition tables. Research organizations, public-health professionals, nutritionists, dietitians, and individuals worldwide rely on the data compiled in USDA Handbook No. 8, "Composition of Foods: Raw, Processed, Prepared." The Human Nutrition Information Service will continue to compile and refine those data. However, to study in certain groups of people the elusive relationship between specific nutrients and physiological function, ARS scientists must chemically analyze the nutrients in the foods that actually are eaten by those people. For such studies, accuracy of the data is critical for trace elements, ultratrace elements, and other nutrients that could be essential in minute amounts, but toxic in larger amounts. Chemical determinations of those nutrients require skilled analysts and are time consuming and costly. To acquire accurate data for the entire diet eaten by individual subjects in the groups studied, we must develop improved methods of sampling and new, automated, and cost-effective methods of analysis.

To understand the role of U.S. agriculture in human health, we should be able to predict the effects that the practices used in all phases of producing, processing, and marketing foods have on the nutritional quality of our diets. The use of fertilizers is an example of practices that can affect the composition of foods. We must study the relationships between the nutrient quality of the samples that are assayed and the history of the foods.

By chemically analyzing samples, we can measure the total amounts of nutrients in a food, but we cannot measure the portion of the total that would be absorbed and used by either laboratory animals or humans. That portion, which indicates the bioavailability of nutrients, can be measured only by bioassays. In our studies of the relationship between diet and the physiological function of people, we must consider the bioavailability, as well as the amounts, of nutrients that foods provide. To determine the bioavailability of specific nutrients in foods, we must develop improved, cost-effective methods for their bioassay. Some nutrients interact with other nutrients, and with some nonnutrients, to alter bioavailability.

Evidence indicates that mineral elements with similar chemical characteristics often compete with one another in plant and animal systems. Zinc and copper interact, and, at marginal levels of nutrient intake, one metal can affect adversely the absorption and metabolism of the other. Interactions of this type are not limited to mineral elements. Absorption of iron is improved by the presence of an animal protein factor or ascorbic acid, or both, and—conversely—absorption of dietary iron, zinc, and calcium can be impaired by phytate and by some components of dietary fiber. People who eat excessive amounts of protein may experience loss of calcium and a weakening of their bones, but some evidence suggests that increased intake of phosphorus prevents calcium losses. We must study specific interactions and assess their importance in human nutrition.

Approach 5.3

Improve the Nutritional Status of Humans and the Well-Being of Families by Making Techniques Available for Assessing the Effectiveness of Nutrition and Home Economics Programs.

Approach Elements

5.3.1 *Provide means for improving understanding of dietary practices, food-consumption patterns, and their determinants through assessments.*

5.3.2 *Develop reliable, efficient, and inexpensive methods for defining nutritional status and evaluating nutrition action programs.*

5.3.3 *Develop methods for improving family economic stability and security.*

We now recognize the need for more sophisticated and accurate methods for assessing the nutritional status of our population. In food-consumption surveys, data usually are collected by the dietary-recall system, which is expensive and prone to errors. The ARS must develop rapid, inexpensive methods for collecting food-consumption data that will accurately reflect dietary habits. In the United States, patterns of dietary practices and habits vary widely among geographic areas, demographic groups, and economic levels. We need more information to understand those patterns and their relation to human health. We must be able to assess and monitor the nutritional status of known high-risk groups—including infants, pregnant and lactating women, the elderly, and the poor. We must also be able to identify other groups of people that could be at high nutritional risk and to monitor changes in their nutritional status.

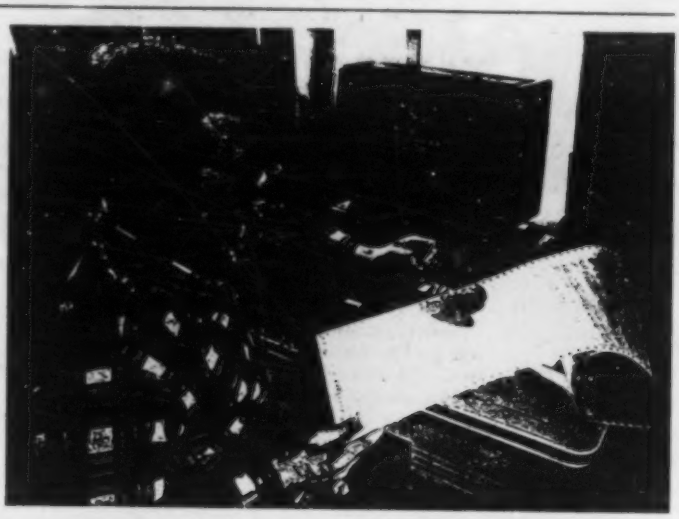
With efficient methods of data collection, scientists should be able to (1) determine what foods people in all groups actually eat and how their eating habits affect their health (2) identify the factors that influence their eating habits; and (3) determine the influence of USDA policies and of programs for nutrition education and intervention on the health, nutritional status, and performance of our citizens.

We know that people with marginal deficiencies in some nutrients suffer altered behavior and impaired performance. Nutrition-related epidemiological research on the many social, environmental, behavioral, economic, cultural, and physiological factors that influence nutritional status will influence the design and evaluation of nutrition action programs. To help ensure the success of such programs, as well as to improve the nutritional status of all our citizens, we must continue our search for biochemical indicators that could be used as simple, specific, and sensitive indexes for evaluating nutritional health. Such indexes also could provide an early warning of potential food and nutrition problems that require remedial action.

As the world's leading producer of food, our agricultural enterprise influences the health of both our citizens and the citizens of the countries that import our farm products. Through its research, ARS will clarify our understanding of the relationship between food and human health and develop improved methods for measuring the true nutritional value of foods for humans. Despite the high cost and complex protocols involved, we must ultimately test our research findings in studies of human subjects. Only the findings from such studies would justify drastic changes of either our procedures for the production, processing, and marketing of foods or our dietary habits. Changes in some of those factors, however, could improve our nutrition and help us increase the degree to which we achieve our genetic potentials.

An integral factor in good nutritional status is effective management of family resources to provide for an adequate amount of nutritious food for all members of the family unit. Some income groups spend the major portion of their wages for food and clothing. However, the food they buy may not meet their nutritional needs. We must find means by which we can help families to manage their resources in a way that will ensure the adequacy of their nutrition and, at the same time, help them achieve economic stability and security.

Objective 6
Develop the Means for Integrating Scientific Knowledge of Agricultural Production, Processing, and Marketing Into Systems That Optimize Resource Management and Facilitate Transfer of Technology to Users



Agriculture must be much more sophisticated in the next century than it is now. We will no longer be able to afford the losses of soil, profligate use of energy and water, and waste of good food that we now tolerate routinely; we must develop systems that conserve those resources. We must integrate data from the basic and applied research—described above in objectives 1 through 5—into models that simulate agricultural activities and practices. Then—by the process of systems analysis—we can compare efficiency among the simulated activities and select those with the most promise for testing and validation in actual experiments. Systems analysis should help increase efficiency in production and marketing, improve assessments of environmental consequences, and foster technology transfer.

Agricultural production must be viewed as a continuum in which financial, human, and natural resources are used for producing, processing, and marketing food and fiber for domestic consumption and export. No part of the continuum can be viewed in isolation because each part affects the other parts. The nutritive value of food and feed and the quality of fiber and other products depend upon the soils, fertilizers, and germplasm used to grow them and the marketing and transportation practices used to handle and deliver them. The costs of agricultural products and the profitability of each phase of agriculture ultimately depend upon the efficiency with which the products are grown and delivered to consumers. As consumers, we are tied fast to farmers and processors, and vice versa. All of us are tied to our resource bases—soil, water, air, germplasm, and energy. Modeling and systems analysis can help us to make this continuum more understandable and manageable and, in many instances, to prevent unwanted side effects.

Many examples, such as improved cropping systems, illustrate the potential power of systems analysis for improving agricultural technology. Traditionally, growers have selected individual technologies "cafeteria style" from those available and tried to use them in their own operations. Modern technologies, however, are becoming so complex and costly that evaluating them by trial and error is no longer practical. To predict which of the available technologies offer the greatest promise of success, we must test them by simulation modeling. For simulations of complex technologies, we must use advanced methods of computing and handling data to incorporate the findings of different scientific disciplines into submodels.

To find the optimum combinations of crops, fertilizers, water management, and pest control for about 10,000 different soils and for the array of diverse climates across the United States, we must integrate the submodels of technologies into models of agricultural systems. To prove which technologies and systems offer the greatest promise for success, we must test the predictions from the models in practical, multivariate field experiments.

Systems analysis also could help to dispel the commonly held notion that high productivity can be attained only at the expense of resource conservation. Because of our great wealth of natural resources, we have not always tried to achieve conservation and productivity simultaneously. The best defense against soil erosion is provided by dense, productive stands of plants that produce ample crop residues. High-yielding crops use about the same amount of water as low-yielding ones, and water-use efficiency is highest when all other growth factors are optimized. The same is true for energy-use efficiency. The challenge, then, is to find ways to reach high and stable levels of crop production with minimum exploitation of limited and expensive resources.

Improvement of the Nation's rangelands offers another opportunity for the use of models. We cannot conduct experiments on all of the more than 30 major rangeland ecosystems in the United States; we can systematically identify needs and make improvements only through the use of models. Models now being developed to quantitatively describe the characteristics of rangelands will simulate the complex functional relationships among soils, water, vegetation, livestock, and climate. Model inputs should include the latest research findings on weed and brush control, water management, reseeding, new grasses, and improved livestock. The natural biota and recreational and scenic values also must be considered. Then, so the results of the simulations will be reliable and useful to ranchers and land managers, we must validate the models by testing their predictions in appropriately located and designed experimental ranges.

We need integrated research in which basic scientific and engineering principles and concepts are applied to the grower-processor-distributor continuum. The location of processing facilities adjacent to production centers and the use of computerized marketing and delivery systems should improve efficiency. Effective coordination among the components of the continuum should prevent excessive losses, maintain the quality of food, and reduce energy consumption.

We need models especially for the development of alternative farming systems. Many people, most of them employed off the farm, use common agricultural practices to farm small acreages. Their operations may be too small for the technologies and marketing systems used by commercial farmers. Many of those people have neither the time to keep up with the latest research findings nor the money to adopt them. Many other people, who may farm either small or large acreages, want to avoid the use of agrichemicals and to maximize the potential for using crop rotations and for recycling animal wastes and crop residues. People in both groups need information that will enable them to make the best long-term use of their resources and to maximize their profits. Many of the same kinds of problems are characteristic of agriculture in the tropical and subtropical zones of the world, and systems analysis can also help solve those problems.

Because modern agriculture is energy-intensive, and energy costs are an increasing burden in all phases of production and marketing, we must conduct research on ways to reduce the dependence of agriculture on fossil fuels. We will include research designed specifically for conserving energy in production, processing, and other phases of agriculture; finding alternative sources of energy, such as biomass, and converting those sources to useful products; substituting wind, solar, and other noncritical sources of energy for fossil fuels; and ameliorating the effects of energy development.

We have sufficient experience with modeling to know that it is effective. The ARS has developed several models—including the Universal Soil Loss Equation (USLE); Modified Universal Soil Loss Equation (MUSLE); Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS); and Simulation of Cotton (SIMCOT)—that simulate major components of agricultural systems. Other organizations have developed economic and management models for agricultural systems that will be useful to ARS. Conversely, agencies such as the Economic Research Service will be able to use those physical and biological models for production forecasts and for economic and policy analyses. The USLE is used worldwide for predicting the effects of management practices on soil erosion. The CREAMS model recently was adopted by the Soil Conservation Service for predicting the effects of different farming practices on water quality.

The ARS and its cooperators have started to integrate submodels into models of large systems. The EPIC (Erosion Productivity Impact Calculator) model, which predicts monthly soil erosion for specific soils by various crop, rotation, and tillage practices, has the following six submodels: (1) soil, water, and nutrient budgets; (2) weather simulation; (3) biomass-crop-growth simulation; (4) tillage- and residue-management simulation; (5) soil erosion; and (6) production-cost budgets. Submodel 6 provides the information—on cost, income, and risk—that farmers need when they adopt conservation practices. The EPIC model should also be useful to many agencies in guiding policy decisions and action programs for crop production and resource conservation; several have expressed interest in using the model. The SPUR (Simulation of Production and Utilization of Rangelands) model is being designed to predict range productivity, evaluate the effects of various management practices, help transfer research results to users, and identify further research needs. It has submodels for climate, hydrology, plants, animals, and insects. Possibilities for technology transfer linkages with economic models and use of remotely sensed data are under investigation for SPUR.

Approach 6.1 **Develop Integrated Systems for Efficiently Producing, Processing, and Marketing Agricultural Products.**

Approach Elements

6.1.1 *Assess and quantify the critical interactions among the different factors needed for producing and marketing food and agricultural products.*

6.1.2 *Develop predictive models for simulating the effects of key physical and biological factors on agricultural productivity and environmental quality.*

6.1.3 *Establish and operate multivariate experiments on integrated agricultural systems to validate models, facilitate technology transfer, and serve as a base for agricultural productivity forecasts.*

6.1.4 *Develop technology for using remotely sensed data to assess and maintain the conditions of our natural resources and to provide information for resource models.*

Problems are typically solved in disciplinary research through the collection of data for individual components—such as soils, plants, insects, and livestock—of a system. Those physical and biological data must be assembled into models of individual systems that can account for the interactions among components. Computer models must accurately and realistically simulate agricultural systems. Their accuracy and validity must be established in appropriate pilot tests and field experiments before the findings can be transferred to users.

The modeling approach has several advantages. First, it is efficient. Time frames of many years can be simulated quickly and inexpensively for many locations and management strategies. Second, an unlimited number of management strategies can be considered, whereas in field experiments only a few can be considered. Third, modeling is a research tool that provides knowledge about agricultural processes and identifies the research that is needed to fill gaps in knowledge. The development of models that simulate specific components of the agricultural system is described in other objectives of the ARS Program Plan. The intent of this objective is to integrate those models of components into models that can simulate even large agricultural systems. Multidisciplinary teams of scientists and engineers will be needed to plan and carry out the modeling and to validate the results.

The ARS has 147 field stations—including instrumented watersheds, range and field research centers, and scientific and engineering laboratories. Cooperating organizations have similar facilities. Many of those stations take measurements and collect data that are useful in the development of submodels and integrated models of systems. "The Census of Agriculture," "Agricultural Statistics," and other references provide information on agricultural production that is useful for developing and testing models. In most instances, multivariate field experiments in various climatic zones or physiographic areas will be required to validate the models. In those experiments, as many as possible of the parameters represented in the models must be individually controlled so that the simulation models will be tested under a wide range of actual conditions. Only then can the results be used with confidence.

An emerging technology—remote sensing—holds great potential for agriculture. Some possible applications include assessing the status of the Nation's resources, estimating the severity of droughts and freezes and their effects on crop yields, scheduling the applications of irrigation water and agricultural chemicals, and forecasting the national or even world production of key agricultural commodities. Many types of sensors may be used, depending upon the kinds of information needed. Types may range from hand-held cameras and radiometers to instruments mounted in airplanes or on satellites. Remote sensing has several potential advantages over conventional technologies, particularly for quickly and inexpensively assessing the condition of crops and soils over large areas.

Data from integrated models, pilot tests, and multivariate field experiments have many practical uses. They can be transferred to potential users, who then can see the actual experimental results and decide which new technologies they want to adopt. Changes in natural-resource bases can be predicted accurately, and steps can be taken to prevent undesirable changes. The field experiments and models will provide a scientific basis for assessing the potential effects, on agriculture, of changes in climate or of increases in carbon dioxide from burning fossil fuels. Similarly, potential adverse side effects of new agricultural technologies can be identified and ways found to mitigate them. Analysis of integrated systems should help to improve the accuracy and timeliness of the Department's forecasts of domestic and foreign production and, in turn, help to reduce speculation and to stabilize commodity markets.

Approach 6.2

Develop Alternative Agricultural Systems, Including Those of Small Scale, That are Less Dependent Upon Nonrenewable Resources and That Are Productive, Efficient, and Sustainable in the Long Term.

Approach Elements

6.2.1 *Develop the means for small-scale commercial farmers and other small-scale producers to maximize efficiency and productivity.*

6.2.2 *Develop productive biological/organic agricultural systems that avoid or minimize the use of nonrenewable inputs, conserve soil and water resources, maintain or increase soil productivity, and produce high-quality products.*

6.2.3 *Develop the knowledge needed for increasing the productivity of tropical/subtropical agricultural systems.*

6.2.4 *Develop systems and technology for reducing the dependence of agriculture on fossil fuels.*

Within the American agricultural community, two groups of producers have some needs that are recognized but are not met through current research programs. Those groups are popularly referred to as "small farmers" and "organic farmers." The inadequacies of those labels notwithstanding, the methods used by the two groups to produce crops and livestock often differ from those used by most large-scale, conventional farmers. Nearly 20 percent of our total food supply comes from the approximately 2 million farms with gross sales of $40,000 or less, and the number of small farms is increasing.

Systems that include the latest technologies for producing, harvesting, processing, storing, and marketing agricultural products could help to reduce costs, ensure conservation of resources, and provide safe and efficient handling of the food produced by that important segment of agriculture. Research on biological nitrogen fixation, biocontrol of weeds and insects, development of better legume varieties, and effects of organic matter on the growth and survival of soil-borne plant pathogens can contribute to systems for organic or low-energy-use farming.

We may be able to develop agricultural production and marketing systems that are applicable to the small-acreage farmer who uses either biological or chemical methods, or a combination of those methods. We should address the needs of the biologically oriented farmer, whether large or small in terms of acreage farmed. The production systems developed should be characterized by less costly methods and by technologies that are safe, sustainable, and environmentally sound. Essential components of the effort should include innovative research to (1) reduce farm production costs while maintaining a high level of sustainable productivity through the development of efficient and diversified crop- and animal-production systems, (2) ensure the conservation of our natural resources, (3) provide safe and economical ways to move agricultural products from the field to the table, and (4) maintain the value and quality of food.

Two other elements of special importance—elements that typically involve a combination of the research efforts described in objectives 1 through 5—are the development of improved farming and marketing systems for tropical and subtropical regions of the world and the development of technologies for reducing the dependence of agriculture on fossil fuels. The ARS must lend its expertise and research capabilities to developing countries, especially those in the tropical and subtropical regions, to help them become self-sufficient. Research in those countries must address the major aspects of agriculture—conservation of resources, improved productivity of crops and livestock, efficient marketing, and improved nutrition of the people.

The ARS also has the capability to help the agricultural industry to conserve fossil energy and, in some instances, to produce alternative energy sources or petrochemical substitutes. Agriculture has the potential for using wind, solar, and other energy sources for activities such as pumping irrigation water, drying grain, and heating farm buildings. Those potentials must be assessed both for conserving energy and for reducing production costs. The waste from one process or activity may be the fuel or feedstock needed for another process or activity, and systems analysis will help identify such opportunities. Biomass, unlike fossil fuels, is renewable, and many scientists think that recent advances in biotechnology hold promise for the use of biomass as a feedstock for industrial processes that yield such products as rubber, resins, terpenes, proteins, waxes, lignin, a variety of carbohydrates, and many others. The production of crops for biomass, chemical feedstocks, and other industrial uses potentially could help farmers to diversify their operations. Through such diversification of U.S. agriculture, farmers would have alternative markets, and the Nation would have domestic supplies of strategic materials for industry.

Implementation Strategy—Policies

Strategic planning is a continuous process of making decisions that are based on the best information available, organizing people and resources to carry out those decisions, and evaluating results against expectations. The Program Strategy describes the kinds of research identified by ARS scientists as necessary to meet the short- and long-term needs of agriculture and presents the minimum number of research approaches needed to meet the goal and objectives of the ARS Program Plan. The research approaches are based on current scientific knowledge and will change as knowledge advances or as the research needs of agriculture change.

The purpose of the Implementation Strategy is to provide guidelines for implementing those portions of the Program Strategy that ARS selects as most likely to succeed in achieving the objectives. As shown in figure 4, the ARS Implementation Strategy includes policies, a Six-Year Implementation Plan, and resource allocations. This section contains the statements of ARS policies for the following key activities:

- National planning and coordination,
- Determination of program content,
- Establishment of priorities,
- Program implementation and management,
- Review and evaluation, and
- International activities.

These policies will guide the development of the ARS Six-Year Implementation Plan and the resource projections now being prepared, as well as the development of operational plans for specific programs. The USDA agencies develop budgets on a 3-year cycle; the Implementation Strategy will encompass two budget cycles. The Administrator of ARS will manage the Agency in accordance with the Six-Year Implementation Plan to mobilize the physical, financial, and human resources of ARS that are necessary for addressing the high-priority needs of agriculture and its beneficiaries.

The policies are statements that establish the principles and standards by which organizational objectives will be realized. Policies must be developed for an organization's key functions, responsibilities, and activities. They also must be understood and followed by all members of the organization so that the efforts to achieve the organization's goals will be cohesive. Policies guide decisions and form a basis for collaboration and teamwork in planning and decisionmaking. The following policies provide a stable framework for maintaining the continuity and flexibility needed to foster scientific excellence and high productivity in the ARS research effort.

Policy 1
National Planning and Coordination

The Administrator Will Operate ARS as a Managed Activity Coordinated by Plan

The Program Strategy describes the research needed to respond to the formidable challenges facing U.S. agriculture. The ARS, the principal intramural research agency in USDA, is—in turn—challenged to focus its scientific resources on the timely solution of the problems it addresses. The ARS Administrator will ensure that needed plans are developed, updated periodically, and implemented to deploy the physical and human resources of ARS to that end. Such plans will provide a framework and sound foundation for:

- Assigning responsibilities for program and administration within the agency;
- Coordinating research across ARS programs, regions, and areas to ensure effective teamwork and to minimize duplication;
- Coordinating ARS research programs with progress of other research performers, such as the State Agricultural Experiment Stations and industry, to ensure that efforts are efficient and complementary;
- Meeting the research needs of those who use agricultural research, including other Federal agencies;
- Setting priorities for allocating and redirecting resources and developing budget requests to promote scientific excellence and to use the talents of the Agency most efficiently;
- Ensuring that effort is productive and balanced among the 6 objectives and 24 research approaches of the ARS Program Plan, as defined in this document;
- Ensuring that problems are addressed by the most appropriate means in terms of key scientific disciplines, teamwork, and technical approach;
- Ensuring that physical and financial resources are available and used effectively;
- Reviewing and evaluating progress toward the achievement of the objectives; and
- Enhancing the opportunity for ARS scientists to innovatively apply their expertise to critical regional, national, and international problems.

The Six-Year Implementation Plan will be the key document in the overall ARS Program Plan. The development and maintenance of the Six-Year Plan are responsibilities of the Deputy Administrator of ARS and the National Program Staff (NPS). Working with line managers, the NPS—in accordance with that Plan—will assess the full spectrum of scientific needs of the Agency, assess the resources that are available for reassignment, and identify program areas that lack resources. Based on the results of

that work, the NPS will develop options and provide, to the Deputy Administrator, recommendations for resource allocations. The Administrator will then select the research programs for implementation by line managers. He will also select from the options those for which the NPS and the ARS Budget Division will develop budget proposals for submission to the Department. Each year, the NPS will adjust the Six-Year Plan based on budgetary decisions and national priorities. Line managers are responsible for updating their operational plans, in accordance with those decisions and priorities, and for implementing their plans. The ARS scientists are responsible for keeping staff members and line managers abreast of the latest scientific advances and opportunities for progress and for ensuring the scientific excellence of their programs. A coordinated ARS effort will ensure that public resources are expended on scientifically excellent and innovative efforts directed toward high-priority problems.

Policy 2
Determination of Program Content

The ARS Research Program Will Include the Full Range of Activities Needed To Achieve the Six Objectives of the Program Strategy

For steady progress toward achieving the six objectives of the Program Strategy, ARS will balance its efforts between basic and applied research. Basic research produces fundamental knowledge that is an essential scientific resource. In their applied research, ARS scientists will draw on that resource to meet the immediate needs of USDA action agencies, other Federal agencies, and users of ARS research findings. By maintaining the balance between basic and applied research, ARS will competently address the critical problems presented in the 6 objectives and 24 research approaches. Basic research programs will be targeted on problem areas in which inadequate fundamental knowledge limits progress. Other programs will exploit existing knowledge bases and breakthrough areas that have a high probability of significant practical payoff. The ARS programs will emphasize long-term, high-risk research that other organizations probably would not attempt. Interdisciplinary research teams will be formed, reorganized, and redirected as needed to ensure that effort is efficiently focused and that the research leads that promise the widest spectrum of benefits are pursued.

The ARS will concentrate on problems of regional, national, and international scope and importance. Problems of more limited scope, such as adapting research findings to local needs and practices, are generally addressed by the State Agricultural Experiment Stations or other research performers unless particular ARS expertise is needed. The ARS will not conduct research that can be conducted better or on a more timely basis by industry. Cooperative research by ARS and State and industrial scientists will be encouraged as an efficient means for increasing the overall benefits that accrue from public investments in agricultural research.

Policy 3
Establishment of Priorities

The Deputy Administrator is Responsible for Establishing Priorities in the Six-Year Implementation Plan and the Derived Budgets. The Administrator Ensures That the Priorities Are Consistent With the Goals of the Department

The priorities established formed the basis for determining program content, for operational planning, and for resource allocations in ARS in three major ways. Priorities will be the foundation for updating the Six-Year Implementation Plan and for planning annual allocations and budget requests. Priorities will guide the allocation of resources in the regions and areas and among competing operational needs. An evaluation of progress in and the plans of each research unit will form the basis for allocations. Research leaders and individual scientists will consider the Agency's priorities in determining which lines of research to pursue within the overall mission of their laboratories and in conformance with the Six-Year Implementation Plan.

Priority setting is complex and dynamic. It is an interactive process among staff and line scientists and includes considerations of both the scientific community and research users. Decisions by the Secretary of Agriculture, Office of Management and Budget, and the Congress will determine the ARS appropriation and can affect the allocation of funds to specific locations and areas of research. Within ARS, individual scientists, along with area and center directors and regional administrators and their staffs, will significantly influence priorities based on their analyses of needs for equipment, facilities, and personnel for exploiting scientific opportunities. Outside of ARS, the Joint Council on Food and Agricultural Sciences and its regional subcommittees, the Users Advisory Board, leaders of farm organizations, industrial groups, and professional societies will influence priorities. The USDA action and regulatory agencies that depend upon ARS for research—agencies such as the Animal and Plant Health Inspection Service, Soil Conservation Service, Food and Nutrition Service, Food Safety and Inspection Service, Agricultural Marketing Service, and Foreign Agricultural Service—will also influence priorities. At times, the research needs of agencies such as the Environmental Protection Agency, Agency for International Development, Department of Defense, National Aeronautics and Space Administration, Extension Service, Forest Service, and Bureau of Land Management will enter the process. Analyses and projections by the Economic Research Service and other agencies also will be considered.

For the setting of priorities, the Administrator will rely on the Deputy Administrator and the NPS to plan, articulate, and evaluate national ARS programs. The NPS identifies research opportunities, research that is conducted by other organizations, and research needs that are expressed by user and advisory groups. The NPS develops recommendations for program redirections and budget requests. Those recommendations will be included in action memoranda, option papers, budget analyses, summaries of program reviews and evaluations, or other appropriate documents. As the direct recipient of the information described above, the Deputy Administrator will establish and articulate ARS priorities. The NPS will update the Six-Year Implementation Plan and, with the ARS Budget Division, develop budgets for that Plan.

The main criteria for setting priorities and allocating resources will be:

- Consistency with the objectives and goals of the Congress, the Department, and the Agency;

- Need for the research as expressed by ARS scientists, user groups, Federal agencies, and the general scientific community;

- Potential benefits expected from achieving the stated objectives;

- Research capabilities and capacity of the scientists, laboratory, or program;

- Probability of success;

- Cost of conducting the research; and

- Amount and kind of research effort conducted by other research organizations.

Several factors may constrain the allocation of resources and kinds of research that ARS conducts and limit the flexibility in resource use. The following factors, which include major constraints, must be considered:

- Availability of scientific expertise. Successful research depends upon the training and experience of individual scientists and upon the teamwork that evolves within and among laboratories. For both individuals and groups, many years are required to reach peak productivity. To help ensure the availability of scientific expertise, the ARS Office of Higher Education will provide guidance on postgraduate and other training opportunities for ARS scientists and others.

- Limitations of geography, climate, and soil. For valid results, certain types of research, especially field research, must be conducted at problem sites and over extended periods.

- Nature of the problem. Much ARS research requires costly facilities and equipment that are problem-specific. Quarantine facilities and special equipment for work on recombinant DNA and foreign animal diseases are examples.

- Sequential nature of research. Often, one phase of research must be completed before the next phase can be started.

- Continuous adaptation of biological systems. Examples are the resistance of crop pests to chemical controls and the genetic improvement of crops that may introduce new vulnerabilities. Goals and priorities must be revised to meet new problems as they arise.

No totally objective formula is possible for setting priorities and allocating resources for research. Priority setting for research is the exercise of informed judgment. It is based on the criteria and constraints listed above; all the factors are important at some level of decision making. At the project level, scientific criteria and experience will predominate. At the national level, scientific criteria must be balanced with Federal policies and with the needs of action agencies and other users of research. It is the task of the Administrator, Deputy Administrator, and the NPS to achieve such a balance so that ARS may provide its scientists with the long-term stability and the firm commitments that are needed for creative research.

Policy 4
Program Implementation and Management

The Regional Administrators are Responsible for the Development and Implementation of Operational Plans for Achieving the Objectives of ARS. The Administrator Is Responsible for Overall Coordination and Execution of the Program

The ARS operates by means of coordinated line and staff activities and responsibilities. Regional Administrators are responsible for field operations managed by four regional offices and staffs, by area directors, and by directors of major research centers. The Deputy Administrator of ARS, located at Headquarters, is responsible for the management and operation of the NPS. The ARS management cadre is responsible for research programs carried out at approximately 150 worldwide locations by 7,600 full-time and 1,000 part-time ARS employees.

The NPS is responsible for developing and providing overall leadership for national research programs in accord with policies 1 and 3. The regional administrators are responsible for operations and operational planning within their respective regions. The staffs for regional program planning and review, the area and center directors, and scientists prepare operational plans in consultation with and subject to review by the NPS. The regional administrators, working with the area and center directors, are responsible for the direct supervision and management of approved research programs and projects. Management support services provide for personnel and for procurement, fiscal, and other functions. Regional administrators are responsible for allocating the resources needed to implement ARS program elements within their regions. They manage the Research Grade Evaluation and Merit Pay Systems by which individual scientists and support personnel are evaluated and rewarded, including the recognition of interdisciplinary research and teamwork.

Line managers play a key role in coordinating research in ARS with that in the Agricultural Experiment Stations, Cooperative Extension Service, Soil Conservation Service, and other agricultural groups of State and regional scope. Through close working relationships with the directors of State Agricultural Experiment Stations, joint research projects, cooperative agreements, and extramural projects are developed as needed to ensure efficient use of ARS personnel and resources.

Line and staff personnel will work together to maintain the integrity and scientific excellence of national programs while efficiently and effectively using ARS resources. The NPS will consult with the regions in developing the ARS priorities and the Six-Year Implementation Plan; the regions will consult and review with the NPS to ensure that the operational plans are consistent with the research objectives and with the priorities of the Six-Year Plan.

Policy 5
Review and Evaluation

The Deputy Administrator Is Responsible for the Systematic Evaluation of Programs and of Progress Toward Achievement of the Six-Year Implementation Plan

The review and evaluation of research programs at many levels in the Agency serve to identify areas of significant progress, major constraints to further progress, emerging research problems and opportunities, and research that can be discontinued. That information will be used in setting priorities, planning and implementing redirections, developing budgets, and revising the Six-Year Implementation Plan and the operational plans.

The NPS is responsible for reviewing national programs and for evaluating their progress and consistency with the Six-Year Plan. To successfully carry out that responsibility, members of the NPS will be recognized experts in their fields and will be expected to maintain their knowledge of the latest scientific aspects of their assigned areas of responsibility. The NPS members will also need broad experience and understanding of interdisciplinary research to recognize and exploit opportunities in related fields or to function as coordinators of problem-solving interdisciplinary teams. They will be prepared to provide authoritative advice as required. Thus, the NPS members serve the Agency as guardians of the continuing relevance and correctness of the technical directions of the ARS program.

The NPS, the Regional Program Planning and Review Staff, and the area and center directors will have operational responsibility for reviewing and evaluating specific programs and units. To spare staff resources, program evaluators will consider the largest practical aggregation of research units. In addition to the appropriate staff and line managers, review and evaluation teams can include top ARS scientists or national technical advisers; representatives from cooperating State Agricultural Experiment Stations, action agencies, and farm and industrial organizations, or other knowledgeable people who can contribute. The review and evaluation teams will develop a formal list of findings and recommendations for implementation by line managers, the scientists, or members of the NPS. (See Directive 600.6.) The regional administrators will then document, and forward to the Deputy Administrator, the plans for and the actions taken to implement the recommendations of the review and evaluation teams.

Area and center directors will review, annually, each research unit and laboratory under their supervision to assess progress on the operational plans and to ensure conformance with the Six-Year Implementation Plan. Although technical matters may be considered, the main purpose of those reviews will be to evaluate operational capability and performance. The adequacy of available physical, financial, and human resources should be assessed, based on the technical objectives to be achieved. Special attention will be given

to identifying opportunities for enhancing technical and leadership capabilities. Findings from and recommendations that result from those reviews will be formally communicated to the Deputy Administrator and to the Regional Program Planning and Review Staff offices.

Scientific and technical excellence demands a continuing review and evaluation of progress by the scientists performing the work. Scientific decisions at the experimental level are best made by those scientists.

Appropriate management information systems will be developed and maintained to meet the specific needs of the Administrator and of the deputy and regional administrators.

Policy 6
International Activities

The ARS Conducts Research and Participates in Technology Exchange in Foreign Countries To Complement and Strengthen Domestic Research Programs, To Support International Trade and Development, and To Carry Out Activities Authorized by the Agriculture and Food Act of 1981

The Administrator of ARS has operating responsibility for international activities. The Assistant to the Administrator for International Activities is responsible for allocation of human and financial resources to foreign activities. The Deputy Administrator and the NPS are responsible for planning, setting priorities, and evaluating international research activities that are an extension of the domestic programs described in the Six-Year Implementation Plan.

As specified in the Agriculture and Food Act of 1981 (Public Law 97-98), ARS also will support U.S. and foreign initiatives that directly benefit U.S. agriculture and provide a substantial contribution to world agriculture. The ARS will work directly with other USDA agencies, such as the Foreign Agricultural Service, Office of International Cooperation and Development, and Animal and Plant Health Inspection Service; other Government agencies, such as the Agency for International Development, Departments of Defense and Commerce, National Science Foundation, and State universities; and international institutions, such as the Food and Agriculture Organization, World Bank, International Atomic Energy Agency, and World Health Organization to produce the greatest benefits from research and technical-exchange programs.

Appendix

The Planning Process

The Agricultural Research Service Program Plan has several purposes. It presents the goal and long-term objectives of the Agency. Those objectives address the current and future needs of agriculture for managing its natural resources, producing and marketing food and other products, and providing nutritious and wholesome foods at reasonable costs. The Plan describes the kinds of research that scientists of the Agricultural Research Service (ARS) think will be needed to achieve the objectives. The intent is to communicate, in an understandable way, the relevance and importance of the agricultural sciences for the future well-being of the United States. The Plan describes the way in which ARS plans to mobilize its scientific resources to help achieve the objectives with a balanced strategy of basic and applied research. The Plan also provides for the continuous review, evaluation, and updating of ARS research to ensure both scientific excellence and continued relevance.

In the first step in the planning process, the goal and six objectives were established. Then, members of the National Program Staff (NPS) drafted a set of 67 proposed courses of action, or research approaches, for achieving the objectives. Each approach was assigned to a selected ARS scientist for further development. Those 67 scientists, who represented many of the 150 ARS locations, then—in turn—enlisted the help of many other scientists to ensure full consideration of commodities, disciplines, and problem areas. More than 500 scientists contributed to the effort. During a period of about 3 months, the scientists developed written materials that defined the scope and scientific content of the approaches. A coordinator for each objective assisted in organizing the written materials. Because of the high cost of holding meetings and workshops, most participants used an electronic mail system to permit maximum interaction and to speed communications.

The scientists concentrated on science and research strategies and avoided defending or projecting current operating programs and organizational structures. Those issues would be addressed later in plans for operations and programs. Scientists organized each research approach into one or more approach elements, which—in turn—contained one or more project areas. A project area was defined as a significant block of scientific work (3 to 10 scientists working with support for 1 year) needed to implement the approaches. The scientists provided the following information for each approach element and project area:

- The nature of the problem to be solved and its scientific and agricultural importance;
- State-of-the-art or current research status and critical research needs or events for further progress;
- The kinds of results expected (reports, vaccines, germplasm, models, etc.) and length of time needed to produce those results;
- Potential benefits and impacts that can be expected if the research is successful;

- Probability of successful achievement; and
- Relative priority of the research.

That information was used to help develop and define the final set of research approaches, approach elements, and project areas. Duplication was eliminated, and only the approaches that were essential to achieve the objectives were selected. Objective coordinators and members of the NPS then developed brief narrative summaries for the final research approaches and approach elements.

The final 24 research approaches that were selected from the 67 originally proposed describe research areas that offer important opportunities for increasing the productivity of agriculture. Examples of those opportunities are improving germplasm resources, reducing losses of crops and livestock, increasing the effectiveness of the marketing sector, and conserving soil and water resources. The research areas described are of lasting importance to agriculture, other agencies, and the public and have high potential for continued progress. A catalog of project areas has been prepared for use in resource projections, but it will not be published. Members of the NPS are now developing the resource projections needed for use in the Six-Year Implementation Plan, which, in turn, will guide the preparation of operational plans by line managers. The Six-Year Implementation Plan and the operational plans will be revised, as appropriate, to reflect the latest scientific findings and most urgent needs of agriculture.

Acknowledgments

This publication was developed under the supervision of Thomas J. Army, Deputy Administrator, NPS, ARS, and chairman of the planning committee, with the guidance of Terry B. Kinney, Jr., Administrator, ARS, USDA. Many others—including vice-chairman Timothy Blosser and objective coordinators Landy Altman, Reginald Handwerk, Charles Kiddy, Waldemar Klassen, Stephen Rawlins, Richard Ridgeway, and Donald Therriault, who made up the planning committee—were deeply involved. Special acknowledgments go to the planning committee and to all of the ARS scientists who participated in development of the Program Strategy. The ARS national research program leaders, NPS chiefs, and others on the NPS played key roles in coordinating and organizing materials for this publication. Warren C. Shaw and Paul A. Putnam were cochairmen of a task force for development of policies, and Essex E. Finney, Jr., was chairman of a committee that assessed future needs for agricultural products and resources.

The Economic Research Service, USDA, provided useful background information and projections. Geri Richmond and Ted Tschudy of the Organization and Management Development Staff were extremely helpful in providing an orderly approach to the planning procedure. The secretarial staff of the NPS was most helpful at all times. Albert R. Grable and Gerald G. Still prepared the final document, and E. Jean Loyd and Annelle C. Black edited it. Michelle Moran and Margaret Theurer typed the many drafts and final copy.

We are indebted to Louis M. Carrese, Associate Director for Program Planning and Analysis, National Cancer Institue, National Institutes of Health, Public Health Service, U.S. Department of Health and Human Services, Bethesda, Md., who was most helpful and generous with his time in presenting seminars, providing advice, and answering questions raised by the planning committee.

The photographs illustrating the goal and objective 2 are by Grant Heilman Photography, Lititz, Pa. The objective 5 cover photograph is by Thomas Zimmerman, Freelance Photographers Guild, New York, N.Y., and the objective 5 text photograph is by Richard Steedman, Stock Market Photography, New York, N.Y.

Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or a warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

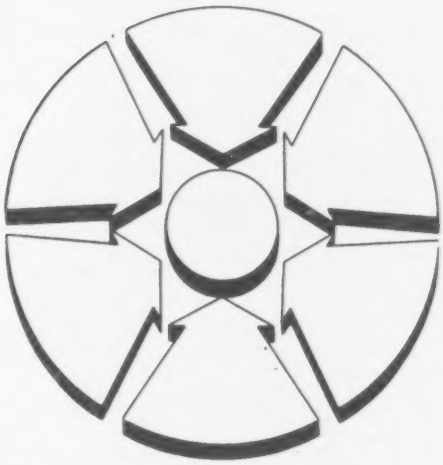
United States
Department of
Agriculture

Agricultural
Research
Service

February 1983

Agricultural Research Service Program Plan

6-Year Implementation Plan, 1984-1990



Contents

INTRODUCTION		1
RESEARCH STRATEGIES		2
	Strategy 1: Mission-oriented, fundamental, long-range, high-risk research	2
	Strategy 2: Integrative systems research	3
	Strategy 3: Efficiency of operation and quality of products, nonrenewable resources, dollar value of agricultural products	3
SUMMARY OF PROGRAM EMPHASIS AND DEEMPHASIS		4
	Specific Program Changes	20
	Alternative Funding Strategies	22
ARS OPERATIONAL PLANS		23
APPENDIX:	ARS OBJECTIVES, APPROACHES, AND APPROACH ELEMENTS	25

Introduction

In the Program Strategy of the Agricultural Research Service (ARS) Program Plan (U.S. Dept. Agr. Misc. Publ. 1429, issued 1983), ARS scientists identified the broad array of research necessary to meet the short- and long-term needs of agriculture. The research was organized into the 6 Objectives, 24 Approaches, and 98 Approach Elements (see Appendix) needed to meet the stated goal. In this 6-Year Implementation Plan, ARS presents those portions of the research described in the Program Plan that will be pursued in the planning period FY 1984-FY 1990.

The Program Plan was developed with a long-term view (20 to 50 years) and under the assumption that funds would be unlimited. In contrast, the 6-Year Implementation Plan was developed under the assumption of finite resources. The 6-Year Plan also reflects the perception, by ARS, of the short-term goals of the Administration and the Congress.

As a statement of ARS program priorities and overall research direction for the planning period, this publication will guide ARS scientists who develop research projects, along with other Agency decision makers at all organizational levels. It also will provide important information to organizations that cooperate with ARS, use ARS research findings, or provide resources for ARS activities. Plans cannot be static. The ARS must respond to expected and unexpected technological advances and research opportunities and to changes in public policy. Therefore, the 6-year plan will be reviewed and updated annually.

The section on Research Strategies, which follows, describes the broad research strategies that will influence the content and direction of the ARS program for the 6-year planning period.

The Summary on Program Emphasis and Deemphasis outlines those portions of the program, by and within objectives, that ARS intends to implement in the 6-year planning period. It specifies the program areas targeted to receive increased or decreased emphasis and projects allocations of funds to the year 1990.

The section on ARS Operational Plans describes the translation of the 6-year plan into operational plans and activities.

Research Strategies

In the Program Plan, the following three major problems were identified as challenges to the long-term ability of the United States to sustain agricultural productivity:

- o World food needs, which will certainly increase with world population over the next 40 years, will be partially met by the United States as a major supplier of agricultural commodities;
- o The decline in quantity and quality of land and water resources continues as more marginal land is put into use and as nonrenewable ground water is exhausted;
- o The annual rate of increase in agricultural productivity is showing signs of declining, and acceleration depends heavily on new technological breakthroughs.

For the period FY 1984 through FY 1990, these long-term challenges must be considered in conjunction with more immediate problems of high-production costs and loss of markets that are faced by U.S. agriculture. Not all these problems can be solved through research; some are problems associated with international trade and monetary policy. However, to the extent these problems might be solved through research, ARS, as the national agricultural research agency, must address them and perform that essential research not being accomplished by others.

Key strategies that guided development of the 6-year plan are as follows.

STRATEGY 1 THE ARS WILL MAINTAIN EMPHASIS ON MISSION-ORIENTED FUNDAMENTAL, LONG-RANGE, HIGH-RISK RESEARCH

For several decades, the generation of fundamental agricultural knowledge, the "seed corn" of technology, has not kept pace with its exploitation into useful technology. That knowledge has been used to solve relatively tractable problems at the expense of generating the new knowledge needed to solve resistant problems. Helping to fill the knowledge gap is clearly a Federal research responsibility, particularly in those rapidly advancing areas that offer potential for increasing agricultural productivity. In the judgment of ARS managers, mission-oriented, fundamental research should account for about 50 percent of the ARS program between 1984 and 1990. Historical and current data for the ARS investment in fundamental research and analysis of the changes in program emphasis projected for the 6 years indicate that the investment in fundamental research will not vary from 50 percent by more than plus or minus 10 percent.

STRATEGY 2

THE ARS WILL INCREASE EMPHASIS ON INTEGRATIVE SYSTEMS RESEARCH

In solving broad regional and national agricultural problems, ARS must consider the effects of a wide spectrum of interactive variables and constraints. To significantly increase agricultural productivity, ARS must devise ways to measure and test factors that affect the efficiency of complex management systems. The intensive farming practices required to increase future productivity require increasingly expensive inputs that will significantly increase the financial risks if crops fail. When agricultural productivity is pushed to the limits, rules of thumb and traditional criteria are inadequate bases for decisions. New management systems and models that account for interactions among components of complex agricultural systems and that accurately predict the consequences of alternative decisions are needed. The ARS is well-qualified for leading team efforts to integrate research approaches that can produce solutions to national problems. For example, producers and processors need predictive management models for making the decisions necessary for timely, appropriate responses to variations in market, weather, pests, costs, and other constraints.

STRATEGY 3

THE ARS WILL EMPHASIZE RESEARCH APPROACHES DIRECTED TOWARD INCREASING EFFICIENCY OF OPERATION AND QUALITY OF PRODUCTS, REDUCING THE USE OF NONRENEWABLE RESOURCES (SOIL, WATER, FUELS) AND INCREASING THE DOLLAR VALUE OF AGRICULTURAL PRODUCTS

Over the long term, U.S. farmers must increase their margin of profit. To that end, ARS will pursue the approaches that are directed toward efficient production, processing, and marketing of high-quality products. Efficiency should help reduce costs of all operations, increase the difference between farmers' dollars of input and of return, and improve the competetive position of U.S. products in domestic and foreign markets. The high quality of farm products should provide similar benefits. With highly efficient operations throughout the agricultural system and reasonable profits for all segments of the system, marginal lands might be withdrawn from production and nonrenewable resources conserved. Such actions should maintain the flexibility the United States might need to respond to national emergencies or shortfalls in production.

Summary of Program Emphasis and Deemphasis

Since 1966, Federal funds for agricultural research have remained about the same on a constant-dollar basis. Recognizing the probability that ARS will continue to have constant-dollar budgets in the foreseeable future, the 6-year plan identifies research program areas targeted for increased emphasis and decreased emphasis within the 1982 level of funding. Resource allocations must be shifted, over time, to achieve a program balance that will be consistent with ARS objectives.

Figure 1 gives the percentage distribution of FY 1982 ARS program funding ($413 million), by the six objectives in the Program Plan. This distribution represents the base from which shifts are planned.

Figure 1. Distribution of funds among objectives of the ARS Program in 1982.

Before decisions were made on the reallocation of funds among objectives of the ARS program, the following factors were considered:

- Production by U.S. agriculture exceeds current domestic needs.
- The United States is facing an indefinite period of surpluses of major agricultural commodities.
- U.S. agricultural products are losing competitiveness in world markets.
- New products are needed for American farm commodities to more successfully compete in world markets.
- Lower production costs are needed for American farm products.
- The U.S. natural resource base is declining.
- Increased emphasis is needed on basic science in agriculture to replenish the dwindling store of basic knowledge.
- More ARS emphasis is needed on fundamental and applied research to increase efficiency of production.
- Integrative systems research is needed to improve the efficiency of U.S. agriculture.
- Improved human nutrition is a national priority.

On the basis of these factors, ARS will appreciably increase its emphasis on commodity conversion and delivery and human nutrition research and modestly increase its emphasis on soil and water conservation and integrative systems research. Without increased funding, ARS must carefully reallocate funds to support essential increases at the expense of some areas of research on plant and animal production. Fundamental productivity research continues to be a national priority. However, significant portions of the conventional, applied, and developmental research components of the ARS program must be assumed by other sectors of the full agricultural research system that are capable of sharing the responsibilities for carrying out that research. Within the ARS productivity research programs that will be continued, long-term fundamental studies will be emphasized to generate the basic knowledge and technology for solving major problems in the efficiency of plant and animal production. Figure 2 gives the planned percentage distribution of total ARS funding, by objectives, for the year 1990.

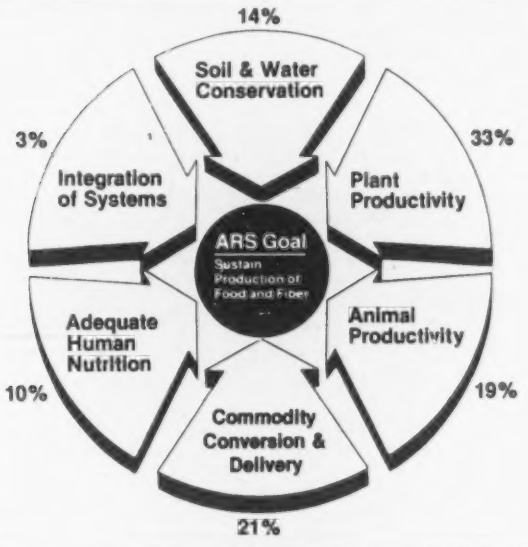


Figure 2. Planned distribution of funds among objectives of the ARS Program for the year 1990.

Table 1 gives the 1982 and targeted distributions of ARS funds, by both dollars and percentages. Also given are the shifts of funds planned within and across objectives to achieve the new program balance.

Table 1 indicates that a total of $75 million in the current base of the ARS program--$33 million across objectives and $42 million within objectives--is targeted for reallocation.

Details of the reallocations for achieving targeted program balance among the approaches and approach elements within each of the six objectives appear in tables 2-7 and in respective bar graphs, figures 3-8. In the tables, only the net shifts of funds from or into an approach element are indicated. Anticipated redirections of funds within approach elements are not indicated. In the figures the differences between the length of the open bar (present level) and the solid bar (targeted level) for each approach element represent the planned amount and direction net change. Major program areas for emphasis and deemphasis are listed after the tables and bar graphs.

TABLE 1. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG OBJECTIVES

Objective	Present Program Balance		Planned Program Changes ($M)			Targeted Program Balance	
	$M	%	Decreases	Increases	Net	$M	%
1 Soil & Water Cons.	52	13	3	9	+ 6	58	14
2 Plant Productivity	165	40	36	7	-29	136	33
3 Animal Productivity	82	20	11	7	- 4	78	19
4 Commodity Conver.	77	18	16	26	+10	87	21
5 Adequate Human Nutri.	27	7	3	17	+14	41	10
6 Integ. of Systems	10	2	6	9	+ 3	13	3
Total	$413	100	$75	$75	$0	$413	100

TABLE 2. OBJECTIVE 1: SOIL AND WATER CONSERVATION. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG APPROACHES AND APPROACH ELEMENTS

Approach Element	Present Program Balance			Planned Program Changes ($M)			Targeted Program Balance		
	$M	%Approach	%Objective	Decreases	Increases	Net	$M	%Approach	%Objective
Assessment									
1.1.1.Land	1.2	22			1.6		2.8	34	
1.1.2 Water	3.2	59					3.2	40	
1.1.3 Air	1.0	19			1.1		2.1	26	
Approach 1.1 Total	5.4	100	10	0	2.7	+2.7	8.1	100	14
Land									
1.2.1 Erosion	4.9	27			0.5		5.4	28	
1.2.2 Fertility	9.3	52			1.4		10.7	56	
1.2.3 Physical	1.3	7			0.8		2.1	11	
1.2.4 Organic	2.5	14		1.6			0.9	5	
Approach 1.2 Total	18.0	100	35	1.6	2.7	+1.1	19.1	100	33
Water									
1.3.1 Use	8.0	33		1.4			6.6	28	
1.3.2 Supply	9.3	38			0.8		10.1	44	
1.3.3 Irrigation	6.9	29		0.5			6.4	28	
Approach 1.3 Total	24.2	100	46	—1.9	0.8	-1.1	23.1	100	40
Systems									
1.4.1 Agricultural	3.6	75			2.7		6.3	84	
1.4.2 Nonagricultural	0	0					0.0		
1.4.3 Environmental	1.2	25					1.2	16	
Approach 1.4 Total	4.8	100	9	0	2.7	+2.7	7.5	100	13
OBJECTIVE 1 Total	52.4		100	3.5	8.9	+5.5	57.8		100

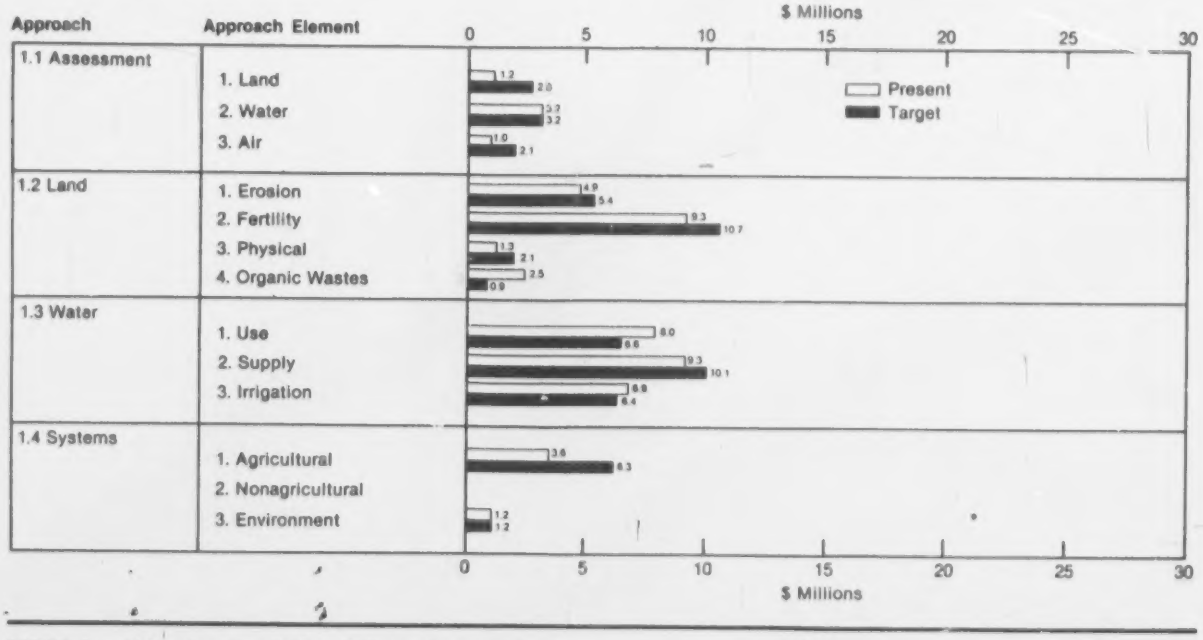


FIGURE 3.--Objective 1. Soil and Water Conservation: Present and targeted approach element allocations.

57-279 O - 87 - 37

TABLE 3. OBJECTIVE 2: PLANT PRODUCTIVITY. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG APPROACHES AND APPROACH ELEMENTS

Approach Element	Present Program Balance			Planned Program Changes ($M)			Targeted Program Balance		
	$M	%Approach	%Objective	Decreases	Increases	Net	$M	%Approach	%Objective
Germplasm Diversity									
2.1.1. Taxonomy	4.3	26					4.3	23	
2.1.2. Acquis.-Crops	9.9	59			1.6		11.5	61	
2.1.3. Acquis.-Pests	2.5	15			0.5		3.0	16	
Approach 2.1 Total	16.7	100	10	0	2.1	+2.1	18.8	100	14
Modify Germplasm									
2.2.1. New methods	4.2	12			1.4		5.6	19	
2.2.2. Range, pasture, for.	4.0	12		0.3			3.7	13	
2.2.3. Field crops	16.5	48		4.9			11.6	40	
2.2.4. Hort. crops	9.7	28		2.0			7.7	26	
2.2.5. Benefical & pests	0.0	0			0.5		0.5	2	
Approach 2.2 Total	34.4	100	21	7.2	1.9	-5.3	29.1	100	21
Crop Productivity, Quality									
2.3.1. Basic biology	13.4	35			0.5		13.9	49	
2.3.2. Range, pasture, for.	8.3	21		2.6			5.7	20	
2.3.3. Field crops	3.7	10		2.0			1.7	6	
2.3.4. Hort. crops	3.3	9		2.0			1.3	5	
2.3.5. Pollination & honey	2.5	6		0.9			1.6	6	
2.3.6. Equip. efficiency	7.4	19		3.4			4.0	14	
Approach 2.3 Total	38.6	100	23	10.9	0.5	-10.4	28.2	100	21
Plant Protection									
2.4.1. Biology-Insects	13.5	18			0.5		14.0	24	
2.4.2. Biology-Plant path.	9.3	12			0.5		9.8	17	
2.4.3. Biology-Nematodes	1.7	2			0.5		2.2	4	
2.4.4. Ins/Dis/Nem-range,past.	1.8	3		0.5			1.3	2	
2.4.5. Ins/Dis/Nem-fld,hort.	27.1	36		12.7			14.4	25	
2.4.6. Biology-Weeds	5.9	8			0.5		6.4	10	
2.4.7. Weeds-Rng,past,for,aq.	2.2	3		0.5			1.7	3	
2.4.8. Weeds-field,hort	3.3	4		1.4			1.9	3	
2.4.9. Biol. control	4.9	7		0.7			4.2	7	
2.4.10.Agr. chem.tech.	4.7	6		2.0			2.7	5	
2.4.11.Vertebrate pests	0.6	1		0.6			-	0	
Approach 2.4 Total	75.0	100	45	18.4	2.0	-16.4	58.6	100	43
Systems									
2.5.1. Assessment	0.5	83			0.5		1.0	63	
2.5.2. Models	0.1	17			0.5		0.6	37	
Approach 2.5 Total	0.6	100	1	0	1.0	+1.0	1.6	100	1
OBJECTIVE 2 Total	165.3		100	36.5	7.5	-29.0	136.3		100

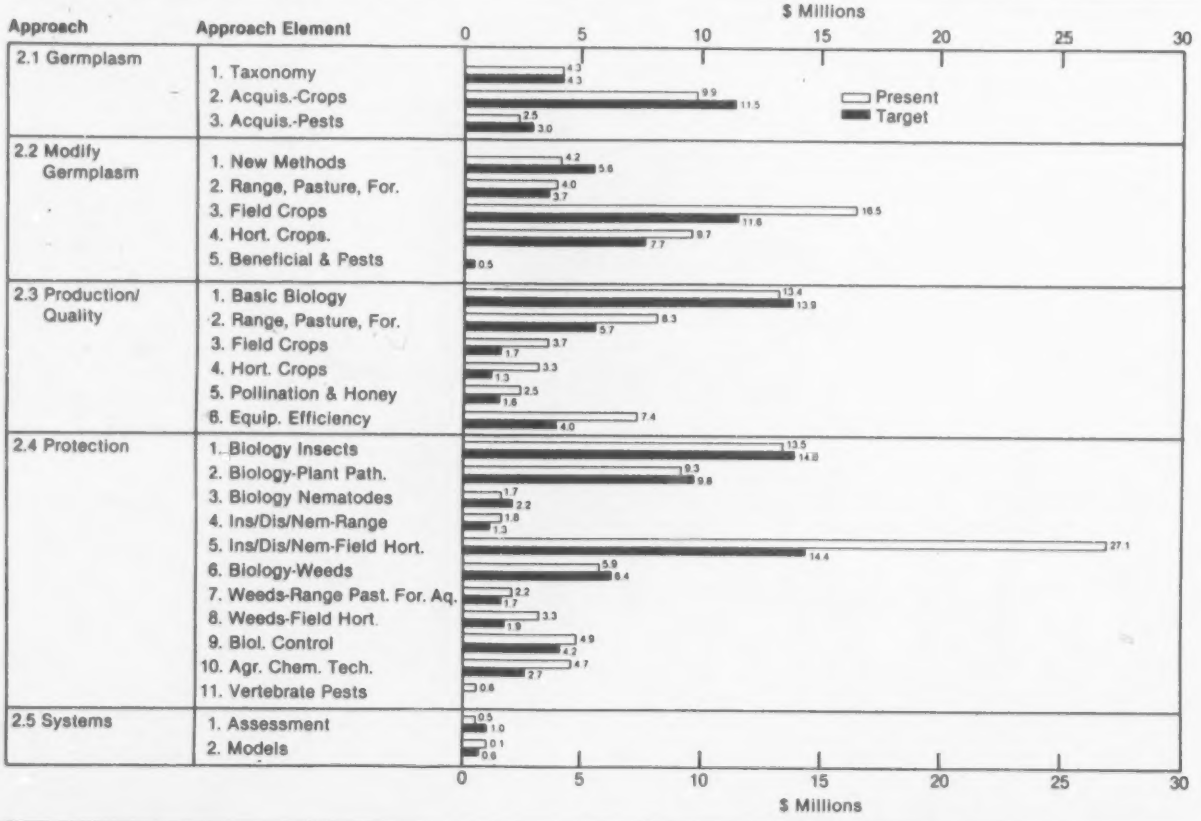


FIGURE 4.--Objective 2. Plant Productivity: Present and targeted approach element allocations.

TABLE 4. OBJECTIVE 3: ANIMAL PRODUCTIVITY. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG APPROACHES AND APPROACH ELEMENTS

Approach Element	Present Program Balance			Planned Program Changes ($M)			Targeted Program Balance		
	$M	%Approach	%Objective	Decreases	Increases	Net	$M	%Approach	%Objective
Genetics									
3.1.1 Selection	4.7	82		1.2			3.5	52	
3.1.2 Gene manipulation	0.4	7		0.4			0	0	
3.1.3 Biochem. genetics	0.6	11			0.5		1.1	16	
3.1.4 Disease resist.	0.0				2.2		2.2	32	
Approach 3.1 Total	5.7	100	7	1.6	2.7	+1.1	6.8	100	9
Reproduction									
3.2.1 Offspring reared	4.0	58		0.4			3.6	49	
3.2.2 Germ cell/embryos	1.2	17			1.0		2.2	30	
3.2.3 Lactations	1.7	25		0.2			1.5	21	
Approach 3.2 Total	6.9	100	8	0.6	1.0	+0.4	7.3	100	9
Nutrition									
3.3.1 Nutrient limits	3.8	36		1.2			2.6	29	
3.3.2 Nutrient losses	4.2	40		1.3			2.9	32	
3.3.3 Synthesis/comp.	2.5	24			1.0		3.5	39	
Approach 3.3 Total	10.5	100	13	2.5	1.0	-1.5	9.0	100	12
Disease									
3.4.1 Diagnosis	9.3	21		0.5		-0.5	8.8	21	
3.4.2 Stress & disease	2.4	6			0.5		2.9	7	
3.4.3 Pathogenesis	10.3	24		1.0			9.3	23	
3.4.4 Disease control	17.2	39		2.2		-2.2	15.0	37	
3.4.5 Toxicology	4.5	10			0.5		5.0	12	
Approach 3.4 Total	43.7	100	53	3.7	1.0	-2.7	41.0	100	52
Insects Ticks & Mites									
3.5.1 Detection	.8	7					0.8	7	
3.5.2 Causal mechanisms	2.1	18					2.1	19	
3.5.3 Reduced losses	5.3	47		1.6			3.7	35	
3.5.4 Integr. systems	1.9	17			1.0		2.9	27	
3.5.5 Human protection	1.3	11					1.3	12	
Approach 3.5 Total	11.4	100	14	1.6	1.0	-0.6	10.8	100	14
Systems									
3.6.1 Shelter	0.2	5		0.2			0		
3.6.2 Feed handling	0.0						0		
3.6.3 Labor efficiency	0.1	2		0.1			0		
3.6.4 Handling/transport	0.1	2		0.1			0		
3.6.5 Manure waste	0.9	24		0.9			0		
3.6.6 Stress	0.1	3			0.6		0.7	22	
3.6.7 Integr. systems	2.5	64					2.5	78	
Approach 3.6 Total	3.9	100	5	1.3	0.6	-0.7	3.2	100	4
Objective 3 Total	82.1	100	100	11.3	7.3	-4.0	78.1	100	100

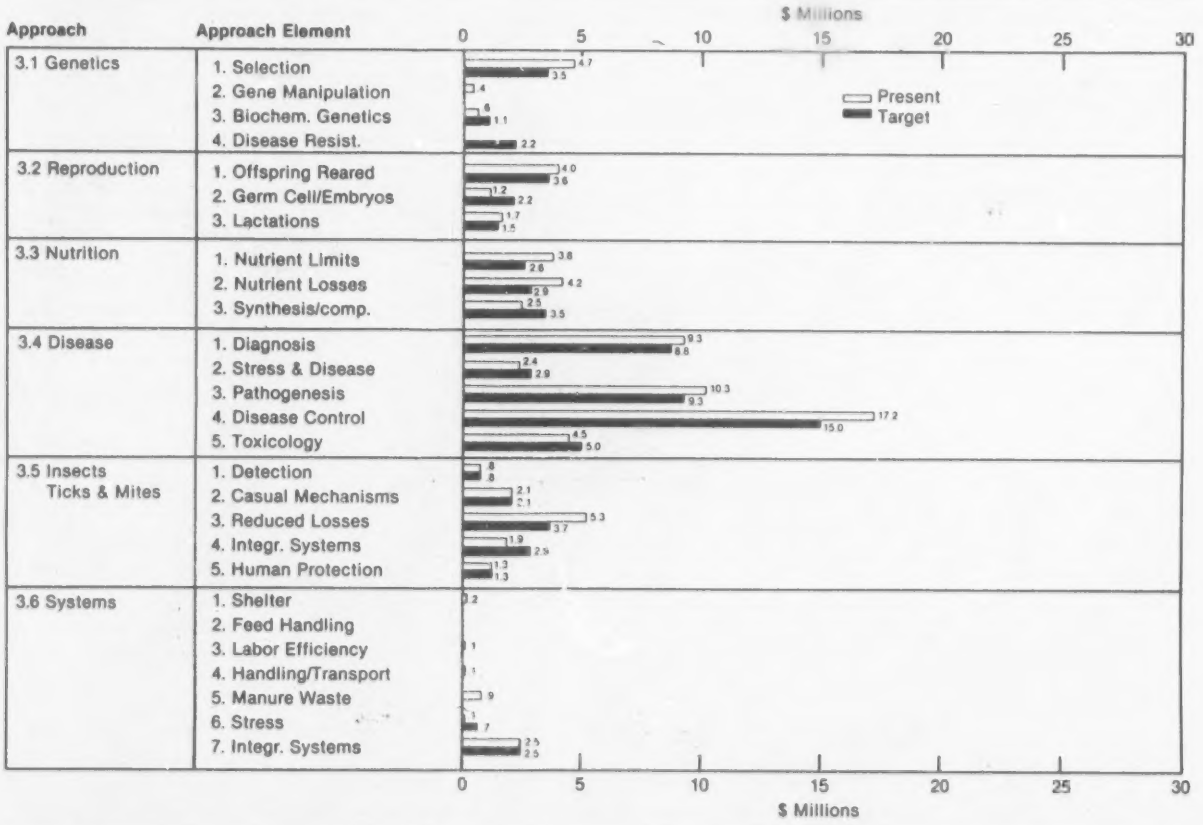


FIGURE 5.--Objective 3. Animal Productivity: Present and targeted approach element allocations.

TABLE 5. OBJECTIVE 4: COMMODITY CONVERSION AND DELIVERY. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG APPROACHES AND APPROACH ELEMENTS

Approach Element	Present Program Balance			Planned Program Changes ($M)			Targeted Program Balance		
	$M	%Approach	%Objective	Decreases	Increases	Net	$M	%Approach	%Objective
Quality									
4.1.1 Characteristics	13.5	38		2.5			11.0	25	
4.1.2 Mechanisms	4.0	11			10.0		14.0	33	
4.1.3 Regulation	1.5	4			5.0		6.5	15	
4.1.4 Products	17.0	47		5.5			11.5	27	
Approach 4.1 Total	36.0	100	47	8.0	15.0	+7.0	43.0	100	49
Safety									
4.2.1 Intrinsic	11.6	52		4.0			7.6	36	
4.2.2 Extrinsic	10.8	48			3.0		13.8	64	
Approach 4.2 Total	22.4	100	29	4.0	3.0	-1.0	21.4	100	25
Loss Reduction									
4.3.1 Insects	5.2	50			1.6		6.8	44	
4.3.2 Microbes	3.0	29			1.5		4.5	29	
4.3.3 Deterioration	1.6	15			2.5		4.1	27	
4.3.4 Physical	0.6	6		0.6			0		
Approach 4.3 Total	10.4	100	13	0.6	5.6	+5.0	15.4	100	18
Systems									
4.4.1 Inefficiencies	1.7	20		1.7			0		
4.4.2 Concepts	2.1	26		1.3			0.8	11	
4.4.3 Grading	2.5	31					2.5	35	
4.4.4 Exports	1.9	23			2.0		3.9	54	
Approach 4.4 Total	8.2	100	11	3.0	2.0	-1.0	7.2	100	8
Objective 4 Total	77.0		100	15.6	26.6	+10.0	87.0		100

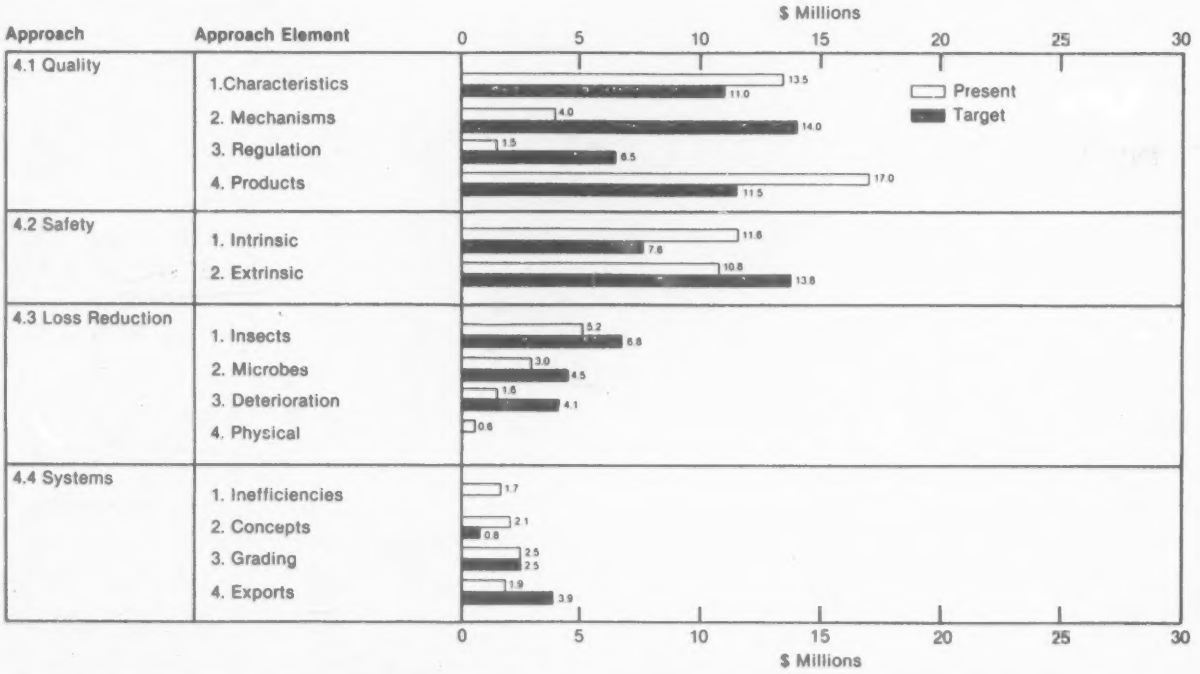


FIGURE 6.--Objective 4. Commodity Conversion and Delivery: Present and targeted approach element allocations.

TABLE 6. OBJECTIVE 5: ADEQUATE HUMAN NUTRITION. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG APPROACHES AND APPROACH ELEMENTS

Approach Element	Present Program Balance			Planned Program Changes ($M)			Targeted Program Balance		
	$M	%Approach	%Objective	Decreases	Increases	Net	$M	%Approach	%Objective
Nutrient Requirements									
5.1.1 Infants & child	1.2	7			2.8	+2.8	4.0	17	
5.1.2 Preg., lact. women	2.2	14			0.8	+0.8	3.0	12	
5.1.3 Adults	7.0	43		0.6		-0.6	6.4	26	
5.1.4 Aging	5.8	36			5.2	+5.2	11.0	45	
Approach 5.1 Total	16.2	100	60	.6	8.8	+8.2	24.4	100	60
Nutrient Comp. & Bioavail.									
5.2.1 Composition	4.0	47		2.0		-2.0	2.0	20	
5.2.2 Bioavailability	4.5	53			3.5	+3.5	8.0	80	
Approach 5.2 Total	8.5	100	31	2.0	3.5	+1.5	10.0	100	24
Nutr. Status Evaluation									
5.3.1 Food composition	0.2	8			0.8	+0.8	1.0	15	
5.3.2 Status methodology	1.8	75			3.2	+3.2	5.0	73	
5.3.3 Family economics	0.4	17			0.4	+0.4	0.8	12	
Approach 5.3 Total	2.4	100	9		4.4	+4.4	6.8	100	16
Objective 5 Total	27.1		100	2.6	16.7	+14.1	41.2		100

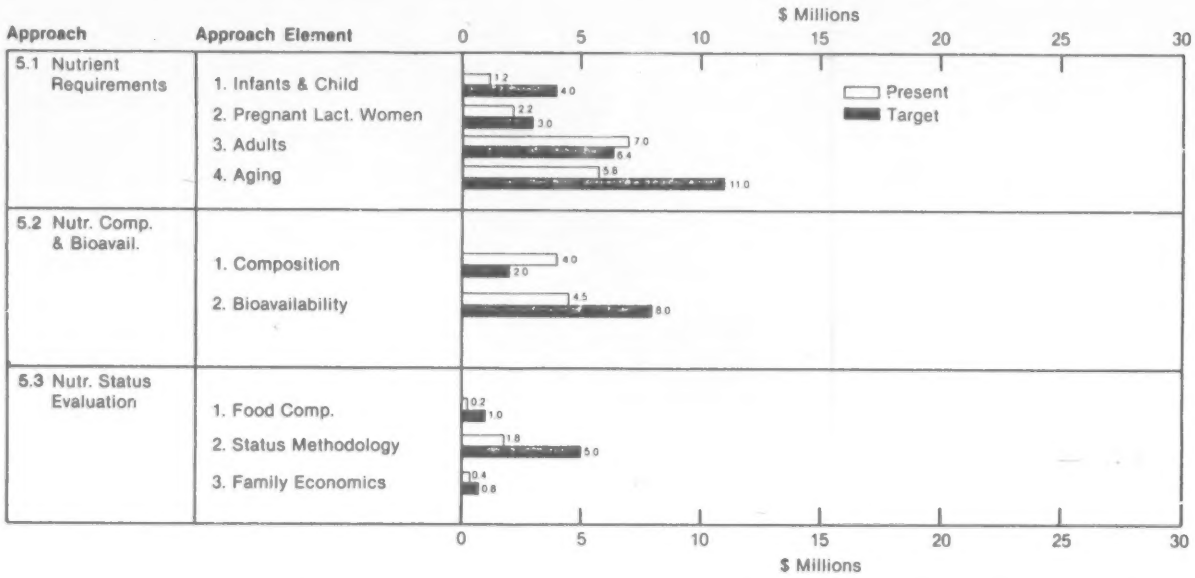


FIGURE 7.--Objective 5. Adequate Human Nutrition: Present and targeted approach element allocations.

TABLE 7. OBJECTIVE 6: INTEGRATION OF SYSTEMS. FUND ALLOCATION STRATEGIES (INCREASES, DECREASES) FOR ACHIEVING TARGETED PROGRAM BALANCE AMONG APPROACHES AND APPROACH ELEMENTS

Approach Element	Present Program Balance			Planned Program Changes ($M)			Targeted Program Balance		
	$M	%Approach	%Objective	Decreases	Increases	Net	$M	%Approach	%Objective
Integrative Systems									
6.1.1.Assessment	0	0			2.7		2.7	25	
6.1.2 Models	1.9	100			1.5		3.4	31	
6.1.3 Validation	0	0			2.8		2.8	26	
6.1.4 Remote Sensing	0	0			2.0		2.0	18	
Approach 6.1 Total	1.9	100	20	0	9.0	+9.0	10.9	100	86
Alternative Systems*									
6.2.1 Small Farms	1.1	14		0.6			0.5	29	
6.2.2 Organic	0	0		0			0	0	
6.2.3 Tropical	3.7	48		3.0			0.7	42	
6.2.4 Energy	2.9	38		2.4			0.5	29	
Approach 6.2 Total	7.7	100	80	6.0	0	-6.0	1.7	100	14
Objective 6 Total	9.6		100	6.0	9.0	+3.0	12.6		100

*Research on components of alternative systems is carried out under other Approaches.

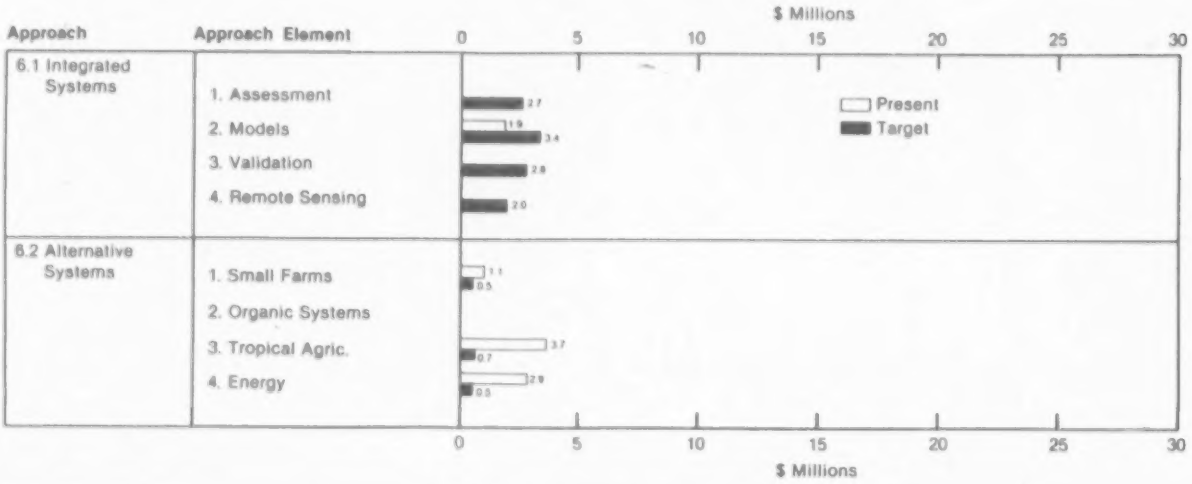


FIGURE 8.--Objective 6. Integration of Systems: Present and targeted approach element allocations.

SPECIFIC PROGRAM CHANGES

Program areas targeted for emphasis and deemphasis within each objective are listed in the outline below. The programs listed are those of major focus and do not include all changes at the approach and approach element levels.

1. Soil and Water

   A. Emphasis: Basic technology for resource assessment, base data for land/water systems analysis and predictive modeling, and programs to improve management of water resources to minimize plant stress.

   B. Deemphasis: Land shaping, engineering-structure development, field evaluation of structures, groundwater recharge, irrigation-hardware development, water-harvesting programs, and municipal and waste utilization.

2. Plant Productivity

   A. Emphasis: Acquisition and maintainence of the genetic diversity of plants, beneficial organisms, and pest species; basic studies on genetic engineering and biology of plants, beneficial organisms and pests; fundamental aspects of crop growth, yield barriers, and management methods.

   B. Deemphasis: Varietal breeding, selected small-commodity programs, location-specific cultural and management practices, pollination and honey production, applied engineering development of equipment for crop production and protection, control of pests with limited geographic or economic significance, applied research on technology for agricultural chemicals, and programs with little potential economic impact.

3. Animal Productivity

   A. Emphasis: Basic studies, at biochemical and physiological levels, on controlling genetic variation; basic research on improving genetic resistance of animals to diseases and parasites; basic studies on increasing reproductive efficiency; mechanisms of nutrient absorption and synthesis of protein and fat; genetic manipulation of pathogens for controlling and preventing disease; and integration of efficiency elements of animal production into total management systems.

B. Deemphasis: Development and field testing of killed and attenuated vaccines, applied insect-control systems, waste management, applied selection and mating programs, and nutrient-limitation work.

4. Commodity Conversion and Delivery

A. Emphasis: Basic mechanisms controlling quality characteristics of marketed products and of means for their genetic and internal control; basic studies on mycotoxin prevention and elimination; basic studies on microbial spoilage agents and pathogen-host associations for preventing contamination; new utilization approaches for exploiting biotechnological advances, adding dollar value, and expanding markets; basic studies of host-pest interactions for reducing losses; basic mechanisms of biodeterioration in harvested plant and post-slaughter animal materials; export grading; and insect and microbial barriers to export.

B. Deemphasis: Food composition, regulatory approvals and registrations, applied product and process improvement, inherent toxic-factor identification and screening, physical losses, and identification of systems inefficiencies.

5. Adequate Human Nutrition

A. Emphasis: Determination of bioavailability of food nutrients and of nutrient requirements for infants, children, and adolescents; nutrition/aging relationships; data bases for improving evaluations of nutritional status.

B. Deemphasis: Nutrient requirement of adults and pregnant/lactating women, nutrient content of foods, dietary practices, and food-composition patterns.

6. Integration of Systems

A. Emphasis: Assimilation and integration of biological and physical research data into systems for analyzing complex interactions of two or more research areas; for example, animals, plants, and environment. Provision of bases for problem identification, and development and validation of predictive models.

B. Deemphasis: Rural housing, small-scale farming, organic farming, tropical agricultural systems, and energy.

ALTERNATIVE FUNDING STRATEGIES

If funding increases, ARS will continue to redirect funds within objectives and approaches as outlined in this 6-year implementation plan and will further increase and accelerate efforts in the high-priority program areas identified for increased emphasis. The 1990 targeted program balance (percentage distribution of funds among objectives) will be maintained with the increases.

If funding decreases, ARS will reduce programs identified for decreases in tables 1-7, while maintaining as near as possible current allocations of funding in areas of program emphasis.

ARS Operational Plans

The ARS 6-year implementation plan provides targets and directions for change in broad program areas. Programs will be adjusted incrementally through internal management and annual budget processes. In some cases, the increment of change in a given program area may be large and abrupt, either early or late in the 6-year planning period; in other cases, the changes will be gradual or in stepwise reallocations throughout the period. In yet others, the planned changes may be modified before actual achievement because the 6-year implementation plan will be updated annually as appropriate to national priorities and policies at the time and depending, partly, on the extent of program changes in the respective current or previous years.

ARS will concentrate effort in high priority program areas and develop centers of specialized research activity. ARS will pursue research for which it can provide the critical mass of resources needed to achieve the planned objectives.

On the basis of this 6-year implementation plan, ARS managers and scientists will develop operational plans that specify (1) project areas for emphasis and deemphasis; (2) timetables for action; and (3) deployment of human, physical, and capital resources for ensuring efficient progress toward the objectives of the ARS Program Plan.

Appendix: ARS Objectives, Approaches, and Approach Elements

OBJECTIVE 1	DEVELOP THE MEANS FOR MANAGING AND CONSERVING THE NATION'S SOIL AND WATER RESOURCES FOR A STABLE AND PRODUCTIVE AGRICULTURE
Approach 1.1	Develop the Technology for Assessing and Predicting Long-Term Changes in the Quantity and Quality of Soil, Water, and Air Resources Available to Agriculture.
Approach Elements	
1.1.1	Develop improved techniques and systems for assessing, predicting, and monitoring changes in the productive capacity of land and soil resources.
1.1.2	Develop improved techniques for assessing and predicting water supplies and their quality.
1.1.3	Develop improved techniques for assessing and predicting the effects of weather and air quality on agricultural productivity.
Approach 1.2	Provide the Technology Needed for Improving, Protecting, and Restoring the Productive Capacity of Agricultural Soils.
Approach Elements	
1.2.1	Develop cost-effective conservation technologies for controlling soil loss from croplands and rangelands.
1.2.2	Devise methods for maintaining and improving soil fertility and the chemical and biological properties of soils for optimum crop production.
1.2.3	Devise techniques for improving, maintaining, or restoring the physical conditions of soils that are needed for optimum crop production.
1.2.4	Devise methods for safely and efficiently recycling municipal and agricultural wastes through croplands.
Approach 1.3	Develop Improved Water-Management Systems and Practices To Achieve Effective and Efficient Use of Water Resources.
Approach Elements	
1.3.1	Optimize the use of water by plants in irrigated and nonirrigated croplands and rangelands to improve and stabilize productivity.
1.3.2	Develop methods for increasing, conserving, and managing water supplies available for agriculture, for improving water quality, and for reducing cropland damage from flooding.

1.3.3	Improve technology for storing and distributing water supplies efficiently and for improving irrigation, drainage, and salinity-control systems and practices.
Approach 1.4	Develop Subsystems and Models That Integrate the Use of Soil, Water, and Air Resources for Optimum Management of Major Land Resource Areas.
Approach Elements	
1.4.1	Develop systems and models for designing resource management strategies that optimize agricultural production and resource conservation.
1.4.2	Develop systems and models for designing resource management strategies that will satisfy the needs of nonagricultural resource uses.
1.4.3	Develop systems and models for designing resource management strategies that are compatible with environmental quality goals.
OBJECTIVE 2	DEVELOP THE MEANS FOR MAINTAINING AND INCREASING THE PRODUCTIVITY AND QUALITY OF CROP PLANTS.
Approach 2.1	Broaden the Germplasm Resources of Plants and Beneficial Organisms To Ensure Maximum Genetic Diversity for Improved Productivity.
Approach Elements	
2.1.1	Develop an understanding of the taxonomic relationships among plants, beneficial organisms, and pests as the basis for research to enhance crop production and protection.
2.1.2	Collect, evaluate, preserve, and make accessible new sources of germplasm of plants and other organisms and assess their potential for meeting agricultural and industrial needs.
2.1.3	Collect, evaluate, preserve, and distribute germplasm of plants and beneficial organisms and of strains of pests that are valuable in pest-management programs.
Approach 2.2	Select and Modify Germplasm of Plants, Beneficial Organisms, and Pests.
Approach Elements	
2.2.1	Devise new methods for modifying germplasm of plants, beneficial organisms, and pests.

	2.2.2	Improve genetic populations of range, pasture, forage, and turf.
	2.2.3	Improve genetic populations of field crops.
	2.2.4	Improve genetic populations of horticultural and specialty crops.
	2.2.5	Improve genetic populations of beneficial organisms, and develop inferior strains of pests that will be useful in pest-management programs.
Approach 2.3		Develop Improved Production Practices for Maintaining and Increasing Crop Productivity and Quality and for Reducing Costs.
Approach Elements		
	2.3.1	Develop knowledge of basic plant growth and development processes of crop species and of micro-organisms of agricultural importance.
	2.3.2	Develop basic ecological principles and improved cultural and management practices for range, pasture, and forage.
	2.3.3	Develop basic ecological principles and improved cultural and management practices for field crops.
	2.3.4	Develop basic ecological principles and improved cultural and management practices for horticultural and specialty crops.
	2.3.5	Develop basic principles for and improved methods of pollination and honey production.
	2.3.6	Discover principles for and develop criteria and specifications for improving the efficiency of agricultural production and protection equipment and practices.
Approach 2.4		Discover Principles and Develop Improved Methods for Reducing Crop Losses Caused by Weeds, Diseases, Insects, Nematodes, and Other Pests.
Approach Elements		
	2.4.1	Develop knowledge of growth, development, and behavioral and population processes of insects as a basis for discovering control principles.

2.4.2 Develop knowledge of etiology, epidemiology, and pathogenicity of plant pathogens as a basis for discovering control principles.

2.4.3 Develop knowledge of growth, development, and behavioral processes of nematodes as a basis for providing control technology.

2.4.4 Provide technology for protecting range, pasture, forage, and turf from losses caused by insects, nematodes, pathogens, and other pests.

2.4.5 Develop principles for protecting field and horticultural crops from losses caused by insects, nematodes, and pathogens.

2.4.6 Develop knowledge of the basic biology of weeds for determining their vulnerability to control.

2.4.7 Develop control technology for reducing losses caused by weeds in forage crops, pastures, rangelands, turf, aquatic environments, and noncroplands.

2.4.8 Develop control technology for reducing losses caused by weeds in field and horticultural crops.

2.4.9 Develop fundamental principles of biological control for pests of crop plants.

2.4.10 Discover principles and develop agricultural chemical technology for reducing crop losses and for modifying plant growth for improved crop protection and production.

2.4.11 Develop fundamental principles for the control of vertebrate pests.

Approach 2.5 Develop Improved Methods for Integrating the Crop- and Pest-Management Practices Needed for Higher and More Stable Levels of Crop Production.

Approach Elements

2.5.1 Develop the means for assessing crop conditions, and identify the factors that limit yields of major crop commodities.

2.5.2 Develop growth and management models for optimum production of crop commodities.

OBJECTIVE 3	DEVELOP THE MEANS FOR INCREASING THE PRODUCTIVITY OF ANIMALS AND THE QUALITY OF ANIMAL PRODUCTS.
Approach 3.1	Increase the Genetic Capacity of Animals for Production.
Approach Elements	
3.1.1	Devise optimum selection and mating procedures for obtaining high levels of animal performance and improved product quality.
3.1.2	Devise procedures for selectively manipulating genetic material to improve desired characteristics.
3.1.3	Determine genetic variation in biochemical, physiological, and behavioral traits of animals, and devise ways for using the information to accelerate genetic improvement.
3.1.4	Improve genetic resistance of animals to diseases and internal and external parasites.
Approach 3.2	Improve the Efficiency of Reproduction and Reproduction-Related Biological Processes.
Approach Elements	
3.2.1	Increase the number of offspring reared per male and female maintained.
3.2.2	Increase efficiency of germ cell and embryo production, transfer, and storage and of techniques for producing more offspring of superior quality.
3.2.3	Increase efficiency and persistence of lactation and egg production.
Approach 3.3	Improve Animal Nutrition and Feed Efficiency To Increase Productivity and Product Quality.
Approach Elements	
3.3.1	Remove nutrient limitations to production.
3.3.2	Reduce losses and inefficiencies in nutrient use, and explore alternative sources of nutrients.
3.3.3	Devise nutritional and physiological means for modifying the rate of synthesis and the composition of animal products.

Approach 3.4	Develop Ways To Prevent or Control Losses From Diseases, Parasites, and Toxicants and Other Substances That Limit Animal Performance and Reduce the Quality of Animal Products.
Approach Elements	
3.4.1	Improve methods for diagnosing and identifying agents that cause losses, and improve methods for assessing those losses.
3.4.2	Establish the roles of environmental stresses and nutrition in losses from diseases and parasites.
3.4.3	Characterize the mechanisms by which animals become infected and are affected by diseases and parasites.
3.4.4	Devise new and improved methods for preventing or reducing death morbidity, and other losses from diseases and parasites.
3.4.5	Prevent, control, or eliminate losses from natural or synthetic substances to which animals may be exposed.
Approach 3.5	Develop Means for Controlling Insects, Ticks, and Mites That Affect Animals and Man.
Approach Elements	
3.5.1	Improve methods of detecting infestations and assessing losses.
3.5.2	Examine mechanisms by which insects, ticks, and mites cause harmful effects.
3.5.3	Devise new and improved methods for reducing losses from insects, ticks, and mites that affect animals and man.
3.5.4	Integrate control technologies into systems approaches for managing insects, ticks, and mites that affect animals and man.
3.5.5	Develop means for protecting humans from insects and insect-borne diseases.
Approach 3.6	Devise Means for Improving and Integrating Procedures and Facilities for Production and Transport of Animals To Increase Productivity, Reduce Costs, and Minimize Stresses.

Approach Elements

3.6.1	Assess environmental impacts and shelter needs for farm animals.
3.6.2	Develop facilities and equipment for feedstuff storage, processing, and distribution.
3.6.3	Develop facilities and equipment for improving animal performance and labor efficiency in production systems.
3.6.4	Develop improved facilities and equipment for handling and transporting animals.
3.6.5	Develop systems for managing and using manure efficiently as a resource.
3.6.6	Devise integrated management practices for maximizing animal productivity and product quality, while minimizing stress.
3.6.7	Evaluate, for optimum use of resources, management programs that integrate all productivity elements under various environmental conditions.

OBJECTIVE 4 — DEVELOP THE MEANS FOR ACHIEVING MAXIMUM USE OF AGRICULTURAL PRODUCTS FOR DOMESTIC MARKETS AND EXPORT.

Approach 4.1 — Develop Means for Enhancing the Inherent Properties and Uses of Agricultural Materials.

Approach Elements

4.1.1	Characterize the basic, physical, chemical, and aesthetic properties of plant and animal materials that enhance their usefulness.
4.1.2	Identify the biological and biochemical mechanisms, in plants and animals, that affect properties of agricultural materials.
4.1.3	Devise means for regulating and controlling the biological processes that enhance usefulness.
4.1.4	Devise concepts for innovative and improved processes and products.

Approach 4.2	Develop the Means for Meeting Foreign and Domestic User and Regulatory Requirements Relating to Toxic Factors in Food, Feed, and Other Agricultural Products.
Approach Elements	
4.2.1	Identify and, when necessary, develop the means for removing intrinsic toxic factors of practical significance.
4.2.2	Identify and, when necessary, develop the means for removing extrinsic toxic factors of practical significance.
Approach 4.3	Develop Means for Reducing or Eliminating Postharvest Losses Caused by Pests, Spoilage, and Physical and Environmental Damage.
Approach Elements	
4.3.1	Develop improved methods for controlling losses caused by insect pests.
4.3.2	Develop improved methods for controlling losses caused by micro-organisms.
4.3.3	Develop improved methods for controlling losses caused by internal chemical and biological mechanisms.
4.3.4	Develop improved methods for controlling losses caused by physical forces.
Approach 4.4	Develop the Means for Increasing Efficiency of Systems for Processing, Handling, Storing, and Distributing Agricultural Products.
Approach Elements	
4.4.1	Identify system inefficiencies.
4.4.2	Devise means for reducing or eliminating inefficiencies.
4.4.3	Devise means for efficiently classifying products for exchange in the marketplace.
4.4.4	Devise means for meeting domestic and foreign quarantine and other requirements that restrict movement and trade of products.

OBJECTIVE 5	DEVELOP THE MEANS FOR PROMOTING OPTIMUM HUMAN HEALTH AND WELL-BEING THROUGH IMPROVED NUTRITION AND FAMILY RESOURCE MANAGEMENT.
Approach 5.1	Define the Nutrient Requirements of Humans at all Stages of the Life Cycle.
Approach Elements	
5.1.1	Establish the nutrient requirements of infants, children, and adolescents.
5.1.2	Establish the nutrient requirements of pregnant and lactating women.
5.1.3	Establish the nutrient requirements of adult humans.
5.1.4	Establish the relationship between nutrition and aging.
Approach 5.2	Determine the Nutrient Content of Agricultural Commodities and Processed Foods as Eaten, and Establish the Bioavailability of Their Nutrients.
Approach Elements	
5.2.1	Compile essential data on the nutrient contents of foods as consumed in the United States.
5.2.2	Determine bioavailability of nutrients in foods as consumed.
Approach 5.3	Improve the Nutritional Status of Humans and the Well-Being of Families by Making Techniques Available for Assessing the Effectiveness of Nutrition and Home Economics Programs.
Approach Elements	
5.3.1	Provide means for improving understanding of dietary practices, food-consumption patterns, and their determinants through assessments.
5.3.2	Develop reliable, efficient, and inexpensive methods for defining nutritional status and evaluating nutrition action programs.
5.3.3	Develop methods for improving family economic stability and security.

OBJECTIVE 6	DEVELOP THE MEANS FOR INTEGRATING SCIENTIFIC KNOWLEDGE OF AGRICULTURAL PRODUCTION, PROCESSING, AND MARKETING INTO SYSTEMS THAT OPTIMIZE RESOURCE MANAGEMENT AND FACILITATE TRANSFER OF TECHNOLOGY TO USERS.
Approach 6.1	Develop Integrated Systems for Efficiently Producing, Processing, and Marketing Agricultural Products.
Approach Elements	
6.1.1	Assess and quantify the critical interactions among the different factors needed for producing and marketing food and agricultural products.
6.1.2	Develop predictive models for simulating the effects of key physical and biological factors on agricultural productivity and environmental quality.
6.1.3	Establish and operate multivariate experiments on integrated agricultural systems to validate models, facilitate technology transfer, and serve as a base for agricultural productivity forecasts.
6.1.4	Develop technology for using remotely sensed data to assess and maintain the conditions of our natural resources and to provide information for resource models.
Approach 6.2	Develop Alternative Agricultural Systems, Including Those of Small Scale, That are Less Dependent Upon Nonrenewable Resources and That Are Productive, Efficient, and Sustainable in the Long Term.
Approach Elements	
6.2.1	Develop the means for small-scale commercial farmers and other small-scale producers to maximize efficiency and productivity.
6.2.2	Develop productive biological/organic agricultural systems that avoid or minimize the use of nonrenewable inputs, conserve soil and water resources, maintain or increase soil productivity, and produce high-quality products.
6.2.3	Develop the knowledge needed for increasing the productivity of tropical/subtropical agricultural systems.
6.2.4	Develop systems and technology for reducing the dependence of agriculture on fossil fuels.

APPENDIX 4

Report of the DoD Laboratory Management Task Force

July 1980

OFFICE OF THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

19 AUG 1980

MEMORANDUM FOR THE DISTRIBUTION

SUBJECT: Forwarding of the DoD Laboratory Management Task Force Report

The Report of the DoD Laboratory Management Task Force is forwarded for your information and use. This Report, which has been approved by the Under Secretary of Defense for Research and Engineering, provides the basis for the Laboratory Management Task Force to proceed, in conjunction with responsible offices in OSD and the Military Departments, to develop action plans to implement the recommendations presented.

I wish to thank the many individuals who contributed to the work of the DoD Laboratory Management Task Force and who participated in developing the Service Laboratory Resource Management plans. The working processes of the Task Force provide an excellent example of how effective communications and teamwork can deal with complex management problems.

These are but the initial steps in our program to maintain the vitality of our DoD Laboratories and to increase their productivity. I solicit the continued support of all members of the DoD R&D management community in this worthwhile endeavor.

Arden L. Bement, Jr.
Deputy Under Secretary of Defense
for Research and Engineering
(Research and Advanced Technology)

Attachment

DoD LABORATORY MANAGEMENT TASK FORCE

FIRST INTERIM REPORT TO THE SECRETARY OF DEFENSE

CHAIRMAN DR. ARDEN L. BEMENT, JR.
DEPUTY UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ENGINEERING
(RESEARCH AND ADVANCED TECHNOLOGY)

JULY 1980

This presentation will provide orientation to the work of the Laboratory Management Task Force and an overview of progress to date. The report contains recommendations for action at various levels of the Office of the Secretary of Defense (OSD) and within the Military Departments. We are firmly convinced that implementation of these recommendations can significantly enhance the vitality of the laboratories and improve the productivity of DoD Research, Development, and Acquisition (RDA) activities.

If implementation is initiated promptly, we believe that the benefits should be fully apparent within two to three years. We also believe that with sustained management attention the contribution of the laboratories can be brought to an all-time peak within the 1980's.

Upon acceptance of the report, it will be provided to the Secretariats of the OSD and the Military Departments, to the Service Acquisition Chiefs, to the Joint Logistics Commanders, and to others including the laboratory communities.

REPORT OUTLINE

BACKGROUND	2
TASK FORCE PARTICIPATION	3
PREVIOUS STUDIES	4-7
THE CURRENT SETTING	8-10
LABORATORIES PROFILE AND ROLES	11-12
TASK FORCE FINDINGS	13
RECOMMENDED ACTIONS	14
ACTION SUMMARIES	15-42
SERVICE PLAN SYNOPSES	43-53

The presentation will cover the above general outline. We will indicate how this effort got started, who the principal players have been, and what those before us did; then give our feelings for the current situation. We will then summarize our findings and recommendations for action, and provide a set of specific analyses and steps for progress.

We emphasize that the Report overview is supported by an extensive array of documentation and participant examinations, including individual Service Laboratory Resource Management Plans.

BACKGROUND

- FIRST JOINT MEETING OF DoD LABORATORY DIRECTORS–JUNE 1978
- REPORT OF AD HOC GROUP TO EXAMINE IMPACT OF MANAGEMENT CONSTRAINTS ON THE DoD LABORATORIES– SEP 1979
- SECDEF MEMORANDUM ESTABLISHING DoD LABORATORY MANAGEMENT TASK FORCE (LMTF)– OCT 1979

The perception that a multiplicity of resource controls on laboratory operations were counterproductive became increasingly evident in the late 1970's. At the 1978 Laboratory Directors Conference, the laboratory community expressed its growing alarm about the adverse effects that individual controls collectively produce. This concern was reiterated at the Congressional level, particularly by the House Armed Services Committee during Fiscal Year 1979 hearings. The declining adequacy of the U.S. military equipment was clearly the concern underlying this attention.

As a result, an ad hoc task group of senior level executives examined the apparent situation. They concluded that the laboratories were being seriously injured by a collection of controls and that the situation was common to the three Services.

Accordingly, these findings were brought to the attention of the Secretary of Defense and he directed the establishment of a formal DoD Laboratory Management Task Force (LMTF) to address ways to improve the vitality of our laboratories. The Task Force operates under the chairmanship of the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology) and is composed of a broad array of senior level representatives from within the DoD.

TASK FORCE PARTICIPATION

COMPOSITION	PRIMARY SUPPORT
OSD	
OUSDRE (R&AT)	OASD (MRA&L)
OASD (MRA&L)	OUSDRE (R&AT)
OASD (C)	
DARPA	
ARMY	
OASA (RDA)	OASA (RDA)
ODCSRDA	HQ DARCOM
HQ DARCOM	HDL
	ARDL / ATL
NAVY	
ASN (RE&S) / DNL	OPNAV
NADC	NADC
NRL	DTNSRDC
	NSWC
	NOSC
	ONR
AIR FORCE	
OASAF (RD&L)	AFWAL
AFSC-DL	AFSC
AFSC-DLZ	

The Task Force initiated operation in January 1980, and is aggressively pursuing the issues as directed by the Secretary of Defense. Service representation is at three levels: the Secretariat, the Staff, and the Field. Additionally, numerous organizations have been assisting the principal members.

REPRESENTATIVE MAJOR STUDIES OF DoD LABORATORIES

- SECDEF TASK 97 STUDY GROUP (1961)
- BELL REPORT (1962)
- TASK 97 ACTION GROUP (1962-1964)
- FEDERAL COUNCIL FOR SCIENCE & TECHNOLOGY (1961-1973)
- CIVIL SERVICE COMMISSION (1967-1968)
- TASK GROUP ON DEFENSE IN-HOUSE LABORATORIES (1971)
- ARMY & NAVY MATERIEL ACQUISITION REVIEWS (1973-1978)
- DoD LABORATORY UTILIZATION STUDY (1975)
- GAO REPORTS ON FEDERAL R&D LABORATORIES (1979)

We are aware that laboratories—whether in Government or industry—are a lightning rod for concerns about science and engineering. The DoD laboratories are no exception. They have been the subject of intensive and recurring studies for several decades. We have tracked studies as far back as one by Dr. Von Karman in 1945.

The slide shows a few of the more significant studies of the past 20 years. We believe it worthwhile to take a few moments to highlight some of the general findings, recommendations, and results of such studies.

PRINCIPAL FINDINGS OF PAST STUDIES

- LABORATORIES VITAL TO DEFENSE RDA
- LABORATORIES CONTRIBUTION IS CONSTRAINED BY–
  - INHIBITING PROCEDURES
  - INADEQUATE PAY
  - AGING FACILITIES
  - MISMATCHED WORKLOAD AND MANPOWER
- CORRECTIVE ACTIONS ARE REQUIRED

Rather consistently, past studies have produced findings essentially the same as those summarized on the chart. Considering the fact that these study groups frequently were composed of eminent people from outside and within the DoD, this general consistency is especially notable. Even within the detailed findings we have found the same high degree of focus.

57-279 O - 87 - 38

GENERAL RECOMMENDATION OF PAST STUDIES

- IMPROVE FACILITIES AND STAFF
- UPLIFT QUALITY OF TECHNICAL LEADERSHIP AND MANAGEMENT
- GIVE LABORATORY LEADERSHIP AUTHORITY AND FLEXIBILITY

Equally noteworthy has been the consistency of the various recommendations.

OBSERVATIONS

- POSITIVE ACTIONS TAKEN WHICH IMPROVED THE ENVIRONMENT FOR LABORATORIES CONTRIBUTION
- BUT–ITS TIME FOR REVITALIZATION
  - CONSTRAINTS ON RESOURCES
    - MULTIPLE
    - INCREASING
    - LEAD TO INEFFICIENCY
  - SHORTAGE OF QUALIFIED SCIENTISTS AND ENGINEERS
    - HIGHLY COMPETITIVE MARKET
    - COMPLEX PERSONNEL AND MANPOWER POLICIES
  - MANAGEMENT AUTHORITY WEAKENED

In general, the recommendations of these past studies have not been ignored. To varying degrees corrective actions have been undertaken—occasionally with striking success. For example, the Bell report resulted in the provision of specific discretionary funds for laboratory directors. The Civil Service Commission study produced significant improvements in personnel procedures. On the other hand, Project REFLEX, a highly regarded initiative to improve civilian manpower management, lost its momentum when the Services were placed under increasingly austere manpower constraints.

R&D managers are fully familiar with encumbrances such as those shown—and with their potential for undermining the contribution of laboratories. The Secretary of Defense recently stated that "periodic reattack of the problem is needed to scrape off the barnacles... fundamental change should also be looked at but will be harder to get barring some catastrophic twist." We agree fully, and, like our predecessors, are working to provide a positive perspective.

THE URGENCY

THE CENTER OF GRAVITY IN THE COMPETITION BETWEEN THE TWO WORLD OPPOSED SYSTEMS IS NOW TO BE FOUND PRECISELY IN THE FIELD OF SCIENCE AND TECHNOLOGY, ... MAKING FURTHER INTENSIVE DEVELOPMENT OF THE LATEST SCIENTIFIC-TECHNICAL ACHIEVEMENTS NOT ONLY THE CENTRAL ECONOMIC BUT ALSO A CRITICAL POLITICAL TASK, AND GIVING QUESTIONS OF SCIENTIFIC-TECHNICAL PROGRESS ... DECISIVE SIGNIFICANCE.

L. I. BREZHNEV

What then is new? What justifies renewed efforts to ensure the vitality of the DoD laboratories? The situation has been brought into all too sharp a focus by Mr. Brezhnev. The U.S. is faced with an extraordinary challenge in the area of technology. The technology challenge is not predominantly economic as in the competition with Germany, Japan, and several others. Technology has now become an extremely critical element in the protection of our national liberty.

THE RDA IMPERATIVE
• IMPROVE MANAGEMENT OF OUR SCIENTIFIC AND TECHNOLOGICAL RESOURCES
• EXPAND OUR TECHNOLOGICAL OPTIONS
– STRENGTHEN TECHNOLOGY
– MAKE BETTER USE OF INDUSTRY BASE
– INCREASE COOPERATION WITH OUR ALLIES
• FIELD SYSTEMS WHICH EFFECTIVELY MEET MISSION NEEDS

Inherent in the urgency must be a continuing concern over the growing quantitative disparity between deployed U.S. and Soviet weapons. Equally important must be concern over significant advances in the quality of Soviet technology and field weapons. These concerns formulate the RDA imperative.

Through the years the in-house laboratories have had key involvements across the spectrum from research to stockpile. As major participants in the technology base and systems acquisition process, the cruciality of their performance becomes increasingly important in times of national urgency. They are a principal player for transferring DoD work to universities and industry. They have major responsibilities both in leading and in assessing the defense RDA work of the private sector.

LABORATORIES PROFILE

- 73 LABS SERVICE MANAGED
- 60,000 PEOPLE–80% CIVILIAN–MEDICAL & AIR FORCE LABS–50% MILITARY
- $5.2 BILLION ANNUAL PROGRAM–40% IN-HOUSE, RDTE $3 BILLION–50% IN-HOUSE
- PHYSICAL INVESTMENT $4 BILLION 50/50 REAL PROPERTY/EQUIPMENT
- SMALL AND LARGE <100 TO >4000
- PHYSICAL SCIENCE, LIFE SCIENCE, & PERSONNEL
- RESEARCH THROUGH THE FULL RDA SPECTRUM

There are over 70 formally recognized DoD in-house laboratories—some large, some small—performing work in the physical, life, and social sciences in support of military and military civil works programs of the DoD. They constitute a large investment of dollars and manpower. Nearly two-thirds of the annual cash flow is RDTE money. About one-half of the R&D funds are contracted to universities and industry; the other half is retained by the laboratories to carry out roles requiring in-house personnel—including extensive activities necessary to support contract work. The balance of these funds are predominately procurement monies that are used for first acquisition of materiel systems and associated support, particularly product improvements. Most of this money is used for industry contracts.

DoD LABORATORY ROLES

- IDENTIFY, EVALUATE, EXPLOIT TECHNOLOGY HANDS-ON
- MINIMIZE TECHNOLOGICAL SURPRISE
- SOPHISTICATED BUYER
- PROCESS TECHNOLOGICAL CONCEPTS TO PROGRAM REALITY
- PERFORM OR MANAGE PROGRAM EXECUTION
- SYSTEMS SUPPORT
- UNDERTAKE ACTIVITIES HAVING EXTRAORDINARY RISK OR REQUIRING QUICK REACTION
- PROVIDE CORPORATE TECHNICAL MEMORY

As major participants in the technology base and in the systems development and acquisition process, the laboratories must respond to DoD needs to:

— Achieve equipment improvements which reduce the impact of projected manpower constraints;

— Obtain lower equipment production, operation, and support costs; and

— Direct substantial R&D effort toward the longer term technological deficiencies and opportunities—particularly through the revitalization of our technology base, the stimulation of prototyping and the use of mature U.S. and Allied technology, and the reduction of intelligence asymmetry and "technological surprises" in the face of a determined and well-supported Soviet competition.

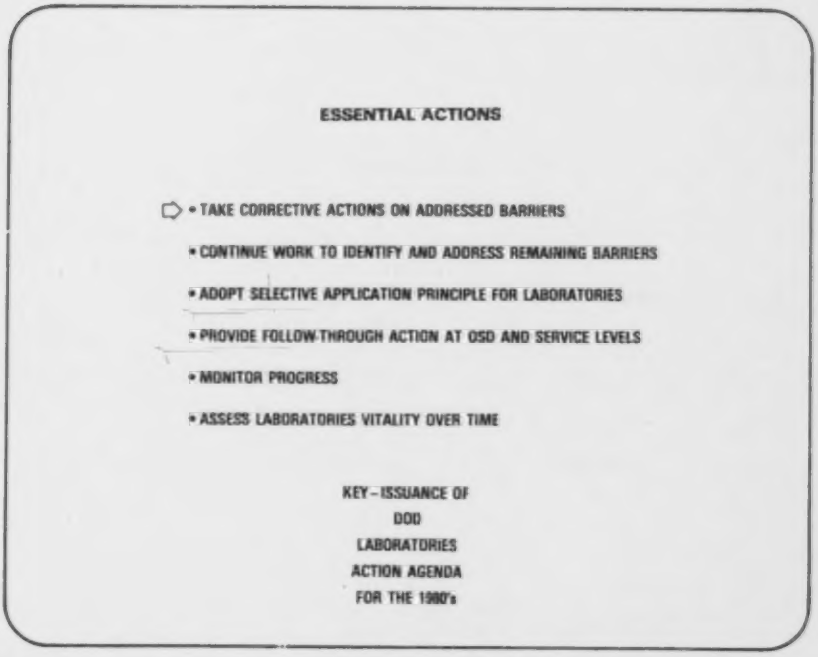
LMTF FINDINGS

THERE ARE SIGNIFICANT BARRIERS IMPEDING EFFECTIVE ROLE PERFORMANCE:

- **MANAGEMENT FLEXIBILITY**
- **STAFF**
- **FACILITIES**
- **EQUIPMENT**

The Task Force's initial job was to access institutional problems. The members compiled analyses of management controls negatively impacting their respective areas of responsibility. This analysis centered primarily on personnel, funding, and contracting issues. Extensive background material was developed. A significant number of barriers have been identified. Most of these are restrictions and limitations placed on the use of specific categories of resources by functional offices outside the RDA management chain. They are usually imposed independently of one another and are often suboptimized with respect to the overall responsibilities of the DoD laboratories. The Task Force then set about determining whether these negative controls were common to all Service laboratories or, conversely, whether the Services were applying controls in notably different manners. The Task Force formulated tentative recommendations which, if implemented, have a high probability of improving the operating environment of the laboratory community.

As suggested by the Secretary of Defense, the Task Force also worked to identify actions of a more fundamental nature which would achieve a high degree of flexibility within a framework of controls that are operationally feasible and acceptable to the OSD and the Services. A significant challenge to the Task Force was their goal of balancing relief mechanisms with monitorship techniques in which top management can have high confidence.

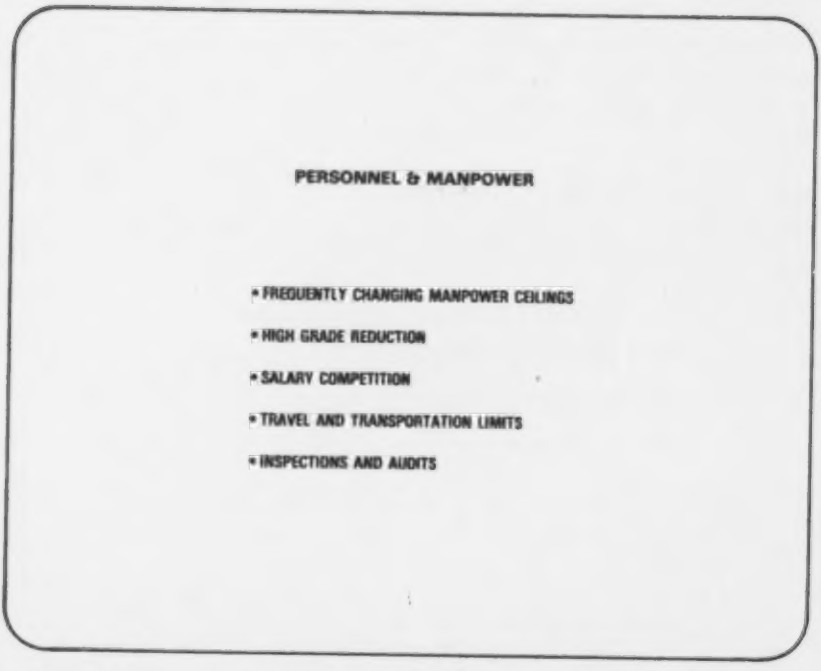

ESSENTIAL ACTIONS
• TAKE CORRECTIVE ACTIONS ON ADDRESSED BARRIERS
• CONTINUE WORK TO IDENTIFY AND ADDRESS REMAINING BARRIERS
• ADOPT SELECTIVE APPLICATION PRINCIPLE FOR LABORATORIES
• PROVIDE FOLLOW-THROUGH ACTION AT OSD AND SERVICE LEVELS
• MONITOR PROGRESS
• ASSESS LABORATORIES VITALITY OVER TIME
KEY–ISSUANCE OF
DOD
LABORATORIES
ACTION AGENDA
FOR THE 1980's

The Task Force has formulated a set of actions which it considers essential to the revitalization of the laboratories. The mechanics of implementing the initiatives contained in these actions vary broadly. Several require the personal support of the Secretary of Defense, others can be placed in effect by coordinative action in the OSD and the Military Departments, and a few can be accomplished within the respective Services.

Our perspective for these actions is both short- and long-term. We are convinced that if meaningful progress is to occur, the DoD must act promptly—and with sustained intensity. If this is not done, the LMTF effort will be just another study of laboratories in a very long list of such studies. Prior studies should be the point of departure; the DoD cannot afford to repeat them. "Backsliding" is a real danger. Our proposals are oriented toward minimizing this fatal weakness.

Accordingly, we will now address each of these actions.

A wide array of barriers impede the performance of the laboratories. The LMTF confined its *initial* efforts to a select group of these barriers—primarily those considered to be particularly inhibiting but subject to reduction. These barriers fell into three groups: Personnel and Manpower (affecting the quality, quantity, and utilization of this key asset); Facilities and Equipment (affecting the inherent capability of the laboratories); and Procurement and Acquisition procedures (affecting the effectiveness of laboratory operations).


PERSONNEL & MANPOWER
• FREQUENTLY CHANGING MANPOWER CEILINGS
• HIGH GRADE REDUCTION
• SALARY COMPETITION
• TRAVEL AND TRANSPORTATION LIMITS
• INSPECTIONS AND AUDITS

Five issues have been addressed, bearing heavily on the workforce and the productivity of that workforce. For each of these issues we have identified the principal problem, impact, and corrective actions. Our recommendation correspondingly suggests who should take action. We have been deliberately precise in this matter: SECDEF means the Secretary of Defense; OSD means the Office of the Secretary of Defense; and DoD means the OSD and the relevant Military Departments.

PERSONNEL & MANPOWER

ISSUE:	• FREQUENTLY CHANGING MANPOWER CEILINGS
PROBLEM:	• SIZE, FREQUENCY AND SCHEDULING OF CHANGES
IMPACTS:	• MANPOWER TURBULENCE (SIZE AND MIX) • INEFFICIENT WORKLOAD PLANNING & EXECUTION • ADMINISTRATIVE BURDEN
ACTIONS:	• CONTINUE EFFORT TO STABILIZE DoD CEILING • DETERMINE THE IMPLICATIONS OF THE PENDING FULL-TIME-EQUIVALENT (FTE) PROCEDURES • REMAIN ALERT TO POSSIBLE CONGRESSIONAL EXEMPTIONS TO CEILINGS FOR INDUSTRIAL FUNDED ACTIVITIES
RECOMMENDATIONS:	• SECDEF CONTINUE TO SEEK STABILIZED CEILING • LMTF EXAMINE FTE IMPACTS ON LABORATORIES • OSD SUPPORT REMOVAL OF CEILINGS FOR LABORATORIES FROM INDUSTRIAL FUNDED LABORATORIES • SECDEF USE DISCRETIONARY AUTHORITY TO STABILIZE LABORATORY CEILINGS

Without doubt manpower ceiling reductions have been the greatest single factor negatively impacting the contribution of the laboratories over the past fifteen or so years. Civilian manpower allocations dominate but military spaces are equally important, particularly in the medical and Air Force laboratories.

The LMTF members expressed very deep concern about this issue, primarily from three standpoints: first, the size of reductions; second, their frequency; and third, their multiplicity. For example, the Army laboratories have been reduced in size more than one-third during the past decade; cuts have occurred every year in one form or another and are continuing; and these cuts come in several forms and at different times during each fiscal year. The turbulence and loss of effectivity caused by this agglomeration of cuts has reached truly serious proportions.

The hire-and-fire practices generally seen in industry are not available to the DoD laboratories as a means of offsetting this instability. Personnel statutes and policies, Congressional constituent interests, and pay restrictions prevent the laboratories from accommodating cuts in an effective manner. As a result the instability has become increasingly debilitating to the laboratories.

It is the opinion of the LMTF that DoD laboratories, in the aggregrate, are now at or below "critical mass" and that any further manpower reductions *cannot* be absorbed without significant negative effects on capability. Action must be taken to obtain a higher degree of ceiling stability. To the degree that this is obtained, the laboratories can institute management initiatives to more effectively meet their missions. If the cut trend is not reversed, closure of laboratories and corresponding mission and workload withdrawals quickly become the only alternative. The array of military technology areas at risk makes relief from current manpower practices an action of the highest urgency.

PERSONNEL & MANPOWER

ISSUE:
- HIGH GRADE REDUCTION FOR CIVILIAN SCIENTISTS AND ENGINEERS AND ASSOCIATED LABORATORY PERSONNEL

PROBLEMS:
- SEC 811(A) OF PL95-79 (FY79 AUTHORIZATION BILL) MANDATES DRAWDOWN
- CIVIL SERVICE REFORM ACT PL95-454 SAVE-GRADE PROVISION NEGATES USE OF DOWNGRADING TO MEET MANDATORY REDUCTION

IMPACTS:
- RESTRICTION DISTORTS GRADE DISTRIBUTION AND MIX
- ADVERSE EFFECTS ON CAREERS PROGRESSION, RETENTION, AND HIRING
- PREORDAINS POORER QUALITY LABORATORIES IN FUTURE

ACTIONS:
- REPEAL SEC 811(A) AS RECOMMENDED IN SEC 803 OF HR 6974 (FY81 AUTHORIZATION)
- MODIFY SEC 811(A) TO LIMIT OVERALL REDUCTION TO THAT ALREADY ACCOMPLISHED
- MODIFY PL95-454 TO ALLOW CREDIT FOR HIGH GRADE POSITIONS DOWNGRADED ALTHOUGH INCUMBENTS RECEIVE SAVE-GRADE
- OBTAIN EXEMPTIONS FOR GS-13'S
- CREATE DEFENSE SCIENCE AND TECHNOLOGY (S&T) SERVICE

RECOMMENDATIONS:
- SECDEF SUPPORT REPEAL OF SEC 811(A) OF PL 95-79
- OSD WORK WITH OPM TO CREATE DEFENSE S&T SERVICE

Section 811(a) of PL95-79 (the Defense Authorization Act of 1978) required the DoD to reduce the number of its civilian employees in grades GS-13 through GS-18 by two percent per year from FY78 through FY80.

The Civil Service Reform Act (CSRA) of 1978 (PL95-454) requires two year save-grade for any employees downgraded since 1 January 1977, through no fault of their own. Clearly, PL95-79 and PL95-454 run contrary in intent. During the FY80 Armed Services hearings this inconsistency became apparent to the Congress and Section 817 of the FY80 Defense Authorization Act was passed to extend the time period or higher grade reductions by one year, to FY81.

Deep concern has already been expressed to the Congress by top officials of the DoD over the impacts of high grade reduction statutes. Section 803 of HR-6974 (the FY81 Defense Authorization Bill) states: "The Committee has since received evidence that the impact of further reductions in the number of supervisory and professional civilians will be detrimental to DoD capabilities, particularly in logistic and research and development functions. For this reason, the Committee recommends the repeal of Section 811(a) that otherwise would require implementation of the final phase of the reduction in FY81."

In the area of research and development, GS-13 scientists and engineers are universally regarded as being at the journeyman level. Rationally, this group should not be considered to be in "high grade" positions. Their inclusion has resulted in striking losses within grade and, equally important, severe losses in lower graded S&E's who see no future in DoD employment.

The DoD must be able to offer adequate career opportunities and status commensurate with responsibilities if it is to retain and attract the high quality talent vital to its mission performance. The criticality of the national S&E situation justifies renewed attention to a special pay group covering defense personnel in the S&E job series, in effect, a Defense Science and Technology Service.

PERSONNEL & MANPOWER

ISSUE:
- SALARY COMPETITION

PROBLEMS:
- NEW AND RECENT GRADUATES
  - SPECIAL SALARY SCHEDULES LIMITED BY 5USC5303
  - S&E GS-5/7 ENTRY LEVELS AT MAXIMUM UNDER LAW GS-9/11 LEVEL INCLUDED BUT NOT AT MAXIMUM
- EXPERIENCED (JOURNEYMEN)
  - 5USC5333 REQUIRES APPOINTMENTS AT STEP 1
  - GS-11/18 HIRING ABOVE STEP 1 REQUIRES AGENCY HEAD AND OPM APPROVAL

IMPACTS:
- NEW AND RECENT GRADUATES – EXISTING RATES INSUFFICIENT TO ATTRACT AND RETAIN MOST S&E SPECIALITIES
- JOURNEYMEN – PROCESS NOT TIMELY (RESULTS IN ESCAPE OF CANDIDATE)

ACTIONS:
- PURSUE ACTION WITH OPM TO ENSURE REPEAL OF SALARY SCALE LIMIT IN 5USC5303
- EXPLOIT RECENTLY DELEGATED AUTHORITY UNDER OPM BULLETIN 300-52 "ADVANCED IN-HIRING RATES BASED ON SUPERIOR QUALIFICATIONS"
- RAISE GS-9/11 S&E TO COMPETITIVE LEVELS

RECOMMENDATION:
- OSD SUPPORT BOTH OF THESE ACTIONS AND WORK TO ADJUST OVERALL S&E PAY SCALE TO PROVIDE MARKET COMPETITION

In the area of science and engineering, Federal pay rates and policies are not comparable with private sector pay for the same level of work. Further action to offset this situation, as permitted by 5USC5301, is seriously lagging. Consequently, the current pay schedules significantly handicap the retention and recruitment of the well-qualified civilian technology personnel required within the DoD laboratory community.

In exercising the authority of the President under Section 5303(a) and (b) of Title 5 United States Code, the Office of Personnel Management (OPM) has issued Special Salary Rate Tables for Professional Engineers which start at the legal maximum (step 10 of basic GS schedule) for grades 5 and 7 and the lower steps of grades 9 and 11. This extension does not meet the pay comparability provisions of 5USC5301.

The 5USC5333 "(triple 3s)" requires that new appointments shall be made at the minimum rate of the appropriate grade. OPM regulations permit exceptions in cases of special need or extraordinarily high qualifications of a candidate. However, the process for obtaining this exception cannot be performed promptly and often the potential employee is lost. OPM Bulletin 300-52 provides a base for improving delegation of authority for advanced in-hiring rates based on superior qualifications. This delegation has recently been signed and must be implemented effectively to allow timely acquisition of qualified journeymen.

Personnel at GS-9 and 11 levels are not addressed adequately in existing procedures. The young scientist or engineer with limited graduate training or job experience is as vitally needed as any other level of employee. Provisions should be sought to ensure continuing comparability of pay for this group. Inequities also exist in the handling of Factor IV (man-in-the-job) situations which cry out for attention if we are to have any semblance of pay comparability for superior employees.

PERSONNEL & MANPOWER

ISSUE:
- TRAVEL AND RECOMMENDATION LIMITS FOR MISSION RELATED WORK

PROBLEMS:
- ADMINISTRATIVE TRAVEL RESTRICTED SINCE FY76 (PL94-157)
- FY80 CONTINUING RESOLUTION (PL96-86) MANDATES $500M FEDERAL TRAVEL CUT
- DoD CUT ($375M) NOW AFFECTS MISSION, TECHNICAL TRAVEL AND TRANSPORTATION OF THINGS (OBJECT CLASS 22) AS WELL AS ADMINISTRATIVE
- INHIBITS PERSONNEL TRANSFERS, EMPLOYMENT, LIAISON, TRAINING, AND SCIENTIFIC EXCHANGE

IMPACTS:
- RESTRICTIONS DIRECTLY IMPACT PROGRAM CONDUCT AND ACCOMPLISHMENT
- FORCES INEFFICIENT USE OF FUNDS AND POSSIBLE BORDER-LINE PRACTICES

ACTIONS:
- URGE CONGRESSIONAL REPEAL OF SEC 112 (PL96-86)

RECOMMENDATION:
- DoD SUPPORT ACTIONS TO REDUCE MISSION IMPACTS

Section 205 of PL94-157 (the FY76 Supplemental Appropriations Act) expressed "the sense of Congress that the President, through the Director of OMB, shall take immediate steps to restrain the inflationary impact of Federal expenditures and to conserve the use of energy by ordering a reduction of Federal travel expenditures not to exceed ten percent." In FY78, the President asked for reduction of FY79 administrative travel costs by twenty percent below the 1979 budget. PL96-86 (the continuing resolution for FY80) mandated a $500M cut across the Government.

Administrative travel has been defined in OMB Bulletin 78-18. The Senate Appropriations Committee in Report 96-393 stated that any evaluation of the amount of administrative travel that is needed to operate the defense establishment must be made separately from those categories of travel that are related to the performance of an organization mission.

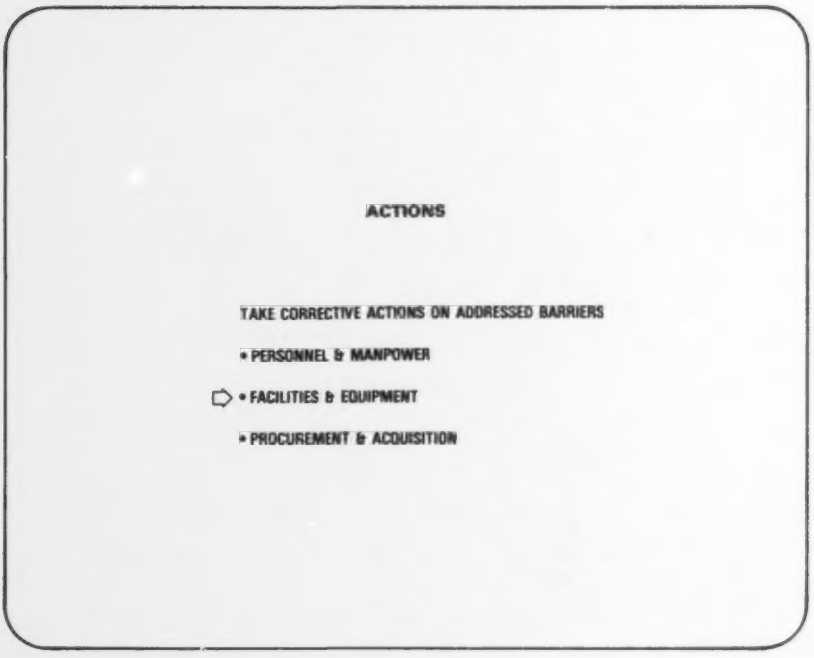
Currently, the foregoing and other travel constraints are producing gross distortions in operating procedures. Laboratory managers are being forced to stretch-the-rules in an effort to avoid technical mission impacts. Their efforts are failing; the mission work is being directly impaired. The transportation of things (object class 22) is every bit as important as transportation of people in the day-to-day operation of laboratories. There is increasing case evidence that a series of well-intended budget constraints are producing counter-productive effects to the severe detriment of the DoD.

It is essential that this situation be mitigated before the impacts become irreversible.

PERSONNEL & MANPOWER

ISSUE:	• INSPECTIONS AND AUDITS
PROBLEMS:	• REPETITIVE, OVERLAPPING, RANDOMLY SCHEDULED INSPECTIONS AND AUDITS DIVERT TECHNICAL MANPOWER FROM PRIMARY MISSION-RELATED TASKS
	• SHORT NOTICE PRECLUDES ADEQUATE PREPARATION OF RESPONSES
IMPACTS:	• DELAY IN PROGRAMS
	• INTERRUPTION OF TECHNICAL ACTIVITIES
	• DIFFICULTY IN PROVIDING ADEQUATE RESPONSES TO LEGITIMATE CONCERNS OF THE INSPECTIONS AND AUDITS ON SHORT NOTICE
	• COSTLY, INEFFICIENT, AND SEEMINGLY EXCESSIVE
ACTIONS:	• DEVELOP UNDERSTANDING WITH INVESTIGATING AND AUDITING BODIES CONCERNING SCHEDULES, DEMAND ON PEOPLE AND FACILITIES, AND PLANNED FREQUENCY AND DURATION OF VISITS
RECOMMENDATIONS:	• OSD TAKE LEAD IN DEVELOPING UNDERSTANDING WITH ITS OWN AND EXTERNAL INVESTIGATING AGENCIES
	• SERVICES DEAL WITH THE PROBLEMS ARISING FROM INTERNAL AUDITS AND INVESTIGATIONS

While little fault can be found with the concept of inspections and audits, the manner of their conduct is proving to be an increasing burden to the laboratories. This situation appears particularly bothersome for laboratories within the National Capital Region (NCR). Easy access, travel constraints, and investigator personal orientations combine to produce seeming inordinate inspections/audits of these laboratories. A not-too-different situation exists for laboratories outside the NCR. The visibility of laboratories in the RDA process probably lies at the heart of this situation. The laboratory community understands this and strives to be cooperative. However, it is being subjected to fragmented and overlapping examinations of the various functional aspects of laboratory operations. Too often, these focus on compliance with specific rules, regulations, and procedures rather than on end results and performance of the organization as a whole. Examination of the details of several such inspections/audits leads the LMTF to suggest that action be taken to secure at least a modicum of constraint and control.



Personnel and Manpower problems are, indeed, imposing. But equally commanding are concerns involving Facilities and Equipment. Without effective tools even the best technology work force can make little contribution.

FACILITIES AND EQUIPMENT

- **INADEQUATE MODERNIZATION OF LABORATORY FACILITIES**
- **INSUFFICIENT MODERNIZATION AND ACQUISITION OF LABORATORY EQUIPMENT**

The $4B investment of the DoD laboratories in facilities and equipment is rapidly becoming inadequate for effective mission performance. Some facilities, which are several decades old but which have received reasonable modernization through the years, remain highly useful. However, others have become, or are becoming, marginal in their utility. The equipment in these facilities is in a similar state. In some instances these tools are merely old; whereas, in other instances they are outdated and inadequate, not because of age but because of the rapid growth of technology and mission requirements. Some are very energy-inefficient. These facilities and equipment are an essential element of the work environment, and consequently greatly affect the productivity of the laboratories.

FACILITIES

ISSUE:
- INADEQUATE MODERNIZATION OF LABORATORY FACILITIES

PROBLEMS:
- MANY FACILITIES ARE SUBSTANDARD / INADEQUATE / OBSOLETE / ENERGY INEFFICIENT
- ADVANCING TECHNOLOGY AND NEW PROGRAMS REQUIRE APPROPRIATE FACILITIES

IMPACTS:
- INHIBITS WORK PRODUCTIVITY AND SLOWS DEVELOPMENTS
- DOES NOT ATTRACT AND SUPPORT HIGHEST QUALITY SCIENTIFIC AND TECHNICAL PERSONNEL
- REDUCES ABILITY TO PROVIDE PROGRAM AND LIFE CYCLE SUPPORT
- FACILITY CONSTRUCTION OFTEN LAGS R&D PROGRAM REQUIREMENTS

ACTIONS:
- ENSURE SIGNIFICANT MONETARY INVESTMENT IN R&D FACILITIES FOR EACH SERVICE OVER NEXT 10 YEARS

RECOMMENDATIONS:
- SECDEF AND DoD ESTABLISH A LABORATORY FACILITIES MODERNIZATION POLICY TO ENSURE REPLACEMENT OF FACILITIES IN A TIMELY MANNER SPECIFICALLY TAILORED TO THE BUSINESS VENTURE CHARACTERISTICS OF LAB SYSTEM (AS A MINIMUM, A FACILITIES MODERNIZATION PROGRAM FOR EACH SERVICE SHOULD BE ABOUT $70M EACH YEAR FOR THE NEXT TEN YEARS)
- OSD SELL THIS POLICY TO THE CONGRESS AND DoD AGGRESSIVELY MONITOR ITS IMPLEMENTATION
- IN ADDITION, DoD SHOULD SUPPORT CONSTRUCTION OF NEW FACILITIES ON A CASE-BY-CASE BASIS

Many of the facilities of the laboratories are the best in the western world. Many other facilities which once met such a criterion no longer qualify. No service remained immune from such deterioration. This decline seriously jeopardizes the ability of the laboratories to meet mission challenges.

A modest modernization program, geared not to mere replacement but to the needs of today and the anticipated future, would be a major positive step toward revitalization of the laboratories. A reasonable goal would be "replacement" of about one-half of the existing facilities over a ten year period. This could be accomplished if, considering inflation, about $200M was provided by Congress for this purpose each year during the 1980's, and if major new facilities were funded over-and-above this replacement action on a case-by-case basis. Procedurally, the initial perspective is that the general limit should be set by relation to specific plan value, over time (e.g., 10-40 years), as practiced in private sector accounting. An excellent study, which can serve as a pilot for other laboratories, was prepared by the Naval Weapons Center (NWC). This study developed a time-phased facilities modernization plan for NWC.

EQUIPMENT

ISSUE:
- INSUFFICIENT MODERNIZATION AND ACQUISITION OF LABORATORY EQUIPMENT

PROBLEMS:
- MUCH LABORATORY EQUIPMENT IS SUBSTANDARD/OBSOLETE
- ADVANCING TECHNOLOGY REQUIRES NEW LABORATORY EQUIPMENT
- GENERAL PURPOSE EQUIPMENT PURCHASES SEVERELY LIMITED
- NO EQUIPMENT RESERVE FUND

IMPACTS:
- INHIBITS WORK PERFORMANCE
- DOES NOT ATTRACT AND SUPPORT HIGH QUALITY SCIENTIFIC AND TECHNICAL PERSONNEL
- COSTLY TO MAINTAIN OLD EQUIPMENT AND WASTES MANPOWER

ACTIONS:
- ESTABLISH CHARGE SYSTEM FOR EQUIPMENT DEPRECIATION
- INCREASE 6.5 RDTE LINE BUDGET FOR EQUIPMENT
- ENSURE SIGNIFICANT MONETARY INVESTMENT IN EQUIPMENT

RECOMMENDATIONS:
- DoD MODIFY EXISTING REGULATIONS (E.G., DoDD 7410.4) TO PERMIT DEPRECIATION CHARGES AT APPROPRIATE LABORATORIES
- SECDEF AND DoD ESTABLISH A LABORATORY EQUIPMENT MODERNIZATION POLICY TO ENSURE THAT GENERAL PURPOSE EQUIPMENT IS REPLACED OR ACQUIRED (IF NEW) IN A TIMELY MANNER (WITH AVERAGE LIFE BASED ON IRS STANDARDS FOR PRIVATE ENTERPRISE)
- EACH SERVICE HAVE AN EQUIPMENT MODERNIZATION PROGRAM OF AT LEAST $25-30M EACH YEAR FOR THE NEXT TEN YEARS

The capacity and capability of a laboratory to perform its assigned roles is as much a function of its equipment as it is of people or other plant operations. The manner in which laboratories are equipped is lacking, primarily because the Services principally fund programs and do not make adequate provision for general purpose/technical equipment needs. (NOTE: the Air Force is a notable exception to this; they fund their laboratories under one line item, RDTE 6.2, and provide for costs of general purpose equipment in the process. However, this 6.2 source is limited.

The DoD, in coordination with the SECDEF, should undertake to establish general purpose depreciation procedures that will provide replacement or acquisition at an adequate rate. Included in this initiative should be a SECDEF policy similar to that recommended for facilities to ensure that the modernization rate is in keeping with the needs of the laboratories and good business practices (e.g., average life of seven years, as used by the Internal Revenue Service for private sector laboratories).

A primary role of the laboratories is support of systems acquisition. Performance of this function and associated support of direct in-house activities requires the laboratories to conduct extensive procurement and acquisition actions. Consequently, contracting procedures lie at the core of laboratory efforts and efficiency.

PROCUREMENT AND ACQUISITION

- DETERMINATIONS AND FINDINGS (D&F) LIMIT AND PROCESS
- CONTRACTING
- NEEDED IMPROVEMENTS IN LABORATORY FINANCIAL MANAGEMENT SYSTEMS

The contracting area is plagued with barriers inhibiting laboratory procurement actions. Institutional procedures are often highly complex and technical. Further, the Congress requires that contracting be one means for redressing societal ills (hence provisions to address small business, freedom of information, and a host of special interests).

Of these many constraints, three have been selected for initial consideration.

PROCUREMENT AND ACQUISITION

ISSUE:	• DETERMINATION AND FINDINGS (D&F) LIMIT AND PROCESS
PROBLEMS:	• D&F $100K LIMIT TOO LOW (D&F HAS 1962 BASE) AND APPROVAL PROCESS TOO LENGTHY
	• USED AS PROGRAM APPROVAL DOCUMENT (NOT LEGISLATIVELY INTENDED)
IMPACT:	• EXTENSIVE REVIEWS AT MULTIPLE LEVELS SIGNIFICANTLY INCREASE TIME REQUIRED FOR CONTRACT AWARD
ACTIONS:	• LEGISLATIVE CHANGES TO INCREASE THRESHOLD FROM $100K TO $1M (52% DECREASE IN ADMINISTRATIVE BURDEN AND YET ONLY 2% OF TOTAL DOLLARS CURRENTLY UNDER D&F'S WOULD NO LONGER REQUIRE SECRETARIAL APPROVAL)
	• INCREASE THE USE OF CLASS D&F'S
	• STREAMLINE PROCESS
RECOMMENDATIONS:	• OSD CONTINUE TO SEEK LEGISLATIVE CHANGES
	• DoD INTERIM MEASURE USE CLASS D&F'S WHEREVER POSSIBLE
	• DoD REDUCE INSTITUTIONAL REVIEWS TO ONE PER LEVEL

The Armed Services Procurement Act (10USC2311) requires that agency heads authorize negotiation of contracts involving more than $100,000 for RDTE work. This dollar level was enacted in 1962, replacing the $25,000 threshold established in 1948 at the inception of the Act.

The number of contracts over $100,000 has been steadily increasing as inflation has reduced the purchasing power of RDTE funds. Determination and Finding (D&F) documentation is required for contracts to perform work pursuant to 10USC2304(a)(11). Consequently, such D&F's pass through multiple review levels to receive Secretarial approval. D&F's are often complex and this staffing time becomes significant to the time needed for contract award.

By "bulking" major planned contracts into one D&F—a class D&F—the approval process can be simplified and also used to discipline early program planning. (NOTE: the Air Force has a very effective class D&F process.) Additional process streamlining could be obtained by instituting parallel coordination procedures for all but the final approval levels.

PROCUREMENT AND ACQUISITION

ISSUE:	• CONTRACTING
PROBLEM:	• MANY DoD LABORATORIES ARE IMPEDED BY LACK OF DEDICATED CONTRACT SUPPORT, LIMITED IMPREST FUND AUTHORITY, LIMITED ACQUISITION AUTHORITY, AND REQUIREMENT TO FOLLOW MAJOR SYSTEM PROCUREMENT FOR NON-MAJOR CONTRACTING
IMPACTS:	• UNACCEPTABLY LONG LEAD TIMES FOR PROCESSING CONTRACTS • SERIOUS DELAYS IN RECEIPT OF SUPPLIES AND SMALL PURCHASES • IMPREST FUND LIMIT DENIES OPERATIONAL FLEXIBILITY • INSUFFICIENT AUTHORITY AT LABORATORY LEVEL TO PROCESS BULK OF CONTRACTUAL WORKLOAD
ACTIONS:	• CHANGE POLICIES TO PROVIDE FOR ADEQUATE CONTRACTING AUTHORITY AND SMALL PURCHASE SUPPORT WITHIN LABORATORIES • RAISE DOLLAR VALUE OF IMPREST FUND AUTHORITY FROM $150/300 TO $300/700
RECOMMENDATIONS:	• DoD PROVIDE DEDICATED R&D CONTRACTING ACTIVITIES FOR LABS • OSD INSTRUCT DEFENSE ACQUISITION REGULATION (DAR) COMMITTEE TO AMEND DAR IMPREST FUND THRESHOLDS • DoD INCREASE SMALL PURCHASE FLEXIBILITY & CONTRACTING AUTHORITY

This initiative addresses several individual but somewhat overlapping problems. One particular barrier to effective laboratory contracting is the lengthening lead times on material and services being procured through consolidated/base/regional contracting offices. This centralization of procurement functions causes work stretch-outs, missed opportunity windows, reduced technological development, and—as a result of frustration—attrition of talented scientists and engineers from the laboratories. The most serious aspect of the problem overall in the laboratory community, is in the small purchase category ($10,000 or less). The impact of constraints associated with small purchases is greatest in the technology base. Equally important is the limitation of contract authority at some laboratories (particularly in the Navy).

Imprest fund thresholds have not kept pace with inflation. Defense Acquisition Regulations (DAR) need revision.

PROCUREMENT & ACQUISITION

ISSUE:
- NEEDED SPECIAL FINANCIAL MANAGEMENT SYSTEMS FOR LABORATORIES

PROBLEMS:
- INDUSTRIAL FUNDING, ALTHOUGH A GENERALLY EFFECTIVE FINANCIAL SYSTEM, DOES NOT ADEQUATELY ADDRESS BARRIERS SUCH AS:
  - RATE STABILIZATION
  - INCREMENTAL FUNDING
  - CONTINUATION OF WORK AT THE BEGINNING OF A NEW FISCAL YEAR
  - MULTIPLE FUNDED CUSTOMER ORDERS
  - FRAGMENTATION OF FUNDING
  - COMMITMENT AND OBLIGATION LEGAL LIABILITIES

IMPACTS:
- DELAYS IN WORK ASSIGNMENT
- LOSS OF PERSONNEL PRODUCTIVITY
- UNFAIR CHARGES TO CUSTOMERS
- IMPRECISE "REAL COST" ANALYSES
- MICRO FISCAL CONTROL SERVING LITTLE USEFUL PURPOSE

ACTIONS:
- ESTABLISH A "SERVICE FUND" APPROACH FOR SELECTIVE USE
- APPLY TO ALL INDUSTRIALLY FUNDED LABORATORIES (ARMY AND NAVY)

RECOMMENDATIONS:
- DoD USING NAVY SERVICE FUND STUDY AT A POINT OF DEPARTURE ESTABLISH AND IMPLEMENT THE SERVICE FUND CONCEPT

The original intent of Industrial Funding in DoD was slanted toward commercial/industrial activities such as depot-level maintenance facilities (e.g., shipyards, aircraft re-work facilities). Currently, OSD policies and procedures for managing such activities often do not fit R&D activities but cause laboratories operating under the industrial fund to confront constraints which, in many cases are counterproductive.

All Navy laboratories (except medical) operate under the industrial funding concept. About one-fifth of the Army laboratories are under industrial funding. The Air Force tried industrial funding at one activity some years ago, did not like it, abandoned it, and now uses "Block" institutional funding. The industrial funding concept gives R&D activities three useful management tools: (1) a working capital fund, (2) a cost accounting system, and (3) a "buyer-seller" relationship between the laboratory and its customers, with charging of all allowable costs (e.g., direct, cost center overhead, general, and administrative expenses) to the specific benefiting users.

One alternative to industrial funding for (Navy) laboratories is the Resources Management System (RMS). One major drawback of the RMS is that it does not provide a working capital fund, a device particularly useful for laboratories.

The Navy has conducted a preliminary study of a modified system which is termed "Service Fund." This system builds upon the flexibility provided in 10USC2208, which provides for "commercial-type" activities as well as industrial-type activities. The establishment of a separate set of procedures under the umbrella of "commercial-type" activities could better provide for the working capital needs of laboratories. Such an approach avoids dilution/change to existing industrial fund policies and regulations and can be adopted by any Service as a stand-alone financial management system if the Service and OSD concur.

ESSENTIAL ACTIONS

- TAKE CORRECTIVE ACTIONS ON ADDRESSED BARRIERS
- CONTINUE WORK TO IDENTIFY AND ADDRESS REMAINING BARRIERS
- ADOPT SELECTIVE APPLICATION PRINCIPLE FOR LABORATORIES
- PROVIDE FOLLOW-THROUGH ACTION AT OSD AND SERVICE LEVELS
- MONITOR PROGRESS
- ASSESS LABORATORIES VITALITY OVER TIME

KEY - ISSUANCE OF:
DoD
LABORATORIES
ACTION AGENDA
FOR THE 1980'S

In addition to the barriers addressed in detail thus far, the LMTF also identified a lesser group of concerns. Several representative concerns are shown for the primary barrier areas on the next three charts. It is the intent of the LMTF to continue its work by addressing these and other yet to be identified concerns, to better ensure that intensive management attention is given to all barriers significantly inhibiting the vitality of the DoD laboratories.

PERSONNEL & MANPOWER
OTHER CONCERNS

- OVERTIME CONTROLS
- CEILING ON EMPLOYMENT IN NATIONAL CAPITAL AREA
- SES / MERIT PAY APPRAISAL TIMING – DoD PERIOD OF 1 JULY – 30 JUNE IS NOT COINCIDENT WITH 1 OCTOBER – 30 SEPTEMBER FISCAL YEAR

FACILITIES AND EQUIPMENT

OTHER CONCERNS

- RAISE LIMIT ON LOCAL APPROVAL FOR USE OF RDT&E FUNDS FOR FACILITIES FROM $100K TO $500K FOR APPROPRIATIONS AVAILABLE FOR OPERATION AND MAINTENANCE
- AMEND 10 U.S. CODE 2353 TO PERMIT THE SAME DEGREE OF FREEDOM TO BUILD FACILITIES IN-HOUSE AS AT CONTRACTORS

PROCUREMENT & ACQUISITION
OTHER CONCERNS

- NEED FOR MULTIPLE YEAR FUNDING OF TECHNOLOGY BASE CONTRACTS
- LACK OF DIFFERENTIATION BETWEEN TECHNOLOGY BASE AND MAJOR PROCUREMENT PRACTICES
- NEED FOR STREAMLINED NEGOTIATIONS

ESSENTIAL ACTIONS

- TAKE CORRECTIVE ACTIONS ON ADDRESSED BARRIERS
- CONTINUE WORK TO IDENTIFY AND ADDRESS REMAINING BARRIERS
- ADOPT SELECTIVE APPLICATION PRINCIPLE FOR LABORATORIES
- PROVIDE FOLLOW-THROUGH ACTION AT OSD AND SERVICE LEVELS
- MONITOR PROGRESS
- ASSESS LABORATORIES VITALITY OVER TIME

KEY–ISSUANCE OF:
DoD
LABORATORIES
ACTION AGENDA
FOR THE 1980'S

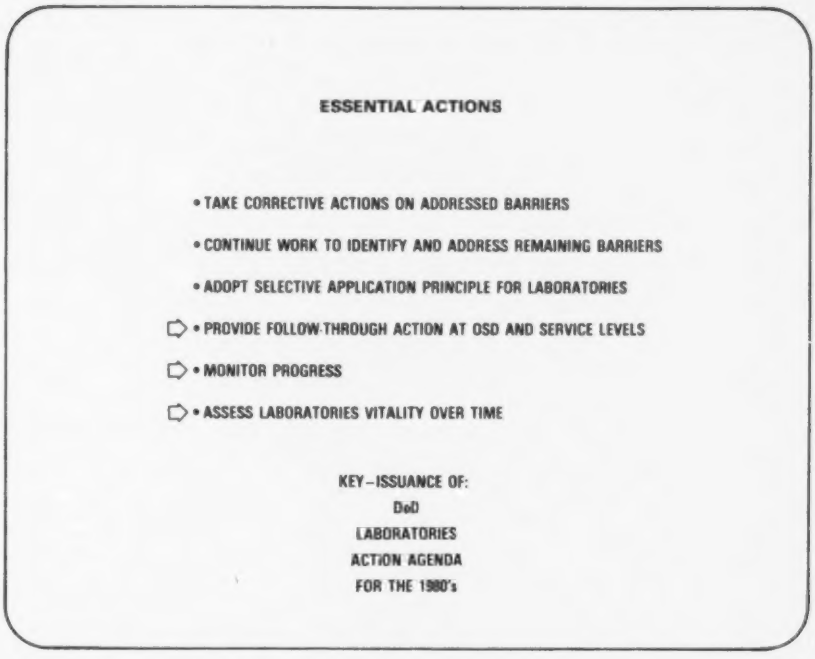
The current constraints on personnel and dollar resources in the face of readiness, modernization, and sustainability needs, places the Services in a series of dilemmas. The requirement to constantly choose between unsatisfactory alternatives is particularly apparent in the Service materiel communities. Senior management must balance R&D, procurement, logistics, maintenance, and a host of other functions to achieve even the semblance of a coherent whole. The choices are tough and rarely palatable. Understandably, these managers are hesitant to "favor" one function at the "expense" of any other. Further, short-term urgencies tend to work against actions supportive to the laboratories multiple roles.

However, the challenge and the urgency are upon us. We see the Soviets entering the decade of the 1980's with a commitment to compete in *quality* with U.S. weapon systems. They have already made a major start in that direction, with the acceptance of the high cost in personnel, facilities, and weapons implied by this commitment. That they plan to continue this emphasis into the 1980's is clear.

The challenge to us is formidable. The LMTF is convinced that the DoD must make a major change in its management of defense technology if we are to maintain a superior technological base, and a competitive and productive industrial and academic team. In order to do this, we recommend that a principle of selective application be instituted in the DoD, with initial application on critical laboratory issues. We believe that this Principle, applied selectively, offers great leverage—a few relatively small changes, in the right places, at the right time, can greatly help to ensure the vitality of DoD laboratories. We believe that this Principle can be applied consistently through the early 1980's without jeopardizing other vital DoD functions and without serious intrusion on the prerogatives of the Military Departments. The Selective Application Principle is set forth in the next slide.

SELECTIVE APPLICATION PRINCIPLE

THE DoD LABORATORIES ARE A KEY AGENT IN ENSURING EFFECTIVE DEFENSE-ORIENTED TECHNOLOGY PROGRAMS. PRIMARY EFFORTS MUST BE FOCUSED ON IMPROVING MANAGEMENT OF OUR SCIENTIFIC AND TECHNOLOGICAL RESOURCES AND ON EXPANDING OUR TECHNOLOGICAL OPTIONS. ACCORDINGLY, THE OSD AND THE MILITARY DEPARTMENTS WILL ADOPT THE PRINCIPLE OF SELECTIVE APPLICATION TO LABORATORIES OF POLICIES AND PROCEDURES WHOSE RIGID APPLICATION INHIBITS EFFECTIVE PERFORMANCE OF ESSENTIAL LABORATORY ROLES. THIS AD HOC POLICY SHALL BE A PRINCIPLE MEANS FOR PROVIDING SIGNIFICANTLY INCREASED AUTHORITY AND FLEXIBILITY TO LABORATORY MANAGEMENT.


ESSENTIAL ACTIONS
• TAKE CORRECTIVE ACTIONS ON ADDRESSED BARRIERS
• CONTINUE WORK TO IDENTIFY AND ADDRESS REMAINING BARRIERS
• ADOPT SELECTIVE APPLICATION PRINCIPLE FOR LABORATORIES
• PROVIDE FOLLOW-THROUGH ACTION AT OSD AND SERVICE LEVELS
• MONITOR PROGRESS
• ASSESS LABORATORIES VITALITY OVER TIME
KEY–ISSUANCE OF:
DoD
LABORATORIES
ACTION AGENDA
FOR THE 1980's

Follow-through, monitoring, and assessment are inherent steps to the resolution of barriers. Considerable attention has been given to these steps by the LMTF. The details of these deliberations will not be given here because of their complexity. The following three slides summarize the intent of each action step.

57-279 O - 87 - 39

FOLLOW-THROUGH

THE APPROVED LABORATORY RESOURCE MANAGEMENT PLANS OF THE SERVICES PROVIDE A BASE FOR FOLLOW-THROUGH WITHIN EACH SERVICE. THESE PLANS ADDRESS SPECIFIC MANAGEMENT CONCERNS TO WHICH THE LMTF INITIATIVES APPLY. THE LMTF WILL IDENTIFY CONTINUING ISSUES AND WORK THROUGH DoD MANAGEMENT TO ACHIEVE THESE CHANGES THAT CANNOT BE WORKED BY THE SERVICES.

MONITORING

THE LMTF WILL SERVE AS A DoD BODY FOR PROGRESS REVIEW. IT WILL ASSESS SPECIFIC PROGRESS IN REMOVAL OF BARRIERS TO EFFECTIVE MANAGEMENT IN THE DoD LABORATORY SYSTEM AND ENCOURAGE THE MILITARY DEPARTMENTS TO SIMILARLY MONITOR SERVICE-UNIQUE ACTIONS.

ASSESSMENT

ASSESSMENT WILL TAKE TWO FORMS:

- INDIVIDUAL LABORATORIES WILL BE ENCOURAGED TO PERFORM SELF-ASSESSMENTS OF THE IMPACT OF BARRIER REDUCTION ON THEIR EFFECTIVENESS. THE LMTF WILL PROVIDE GUIDELINES TO ASSIST THIS SELF-ASSESSMENT
- THE LMTF MEMBERS WILL CONDUCT SELECTED ASSESSMENTS TO DETERMINE IF CORRECTIVE MEASURES ARE EFFECTIVE--AND FOCUS ATTENTION UPWARD THROUGH OSD AS WELL AS DOWNWARD TOWARD THE LABORATORIES

ESSENTIAL ACTIONS

- TAKE CORRECTIVE ACTIONS ON ADDRESSED BARRIERS
- CONTINUE WORK TO IDENTIFY AND ADDRESS REMAINING BARRIERS
- ADOPT SELECTIVE APPLICATION PRINCIPLE FOR LABORATORIES
- PROVIDE FOLLOW-THROUGH ACTION AT OSD AND SERVICE LEVELS
- MONITOR PROGRESS
- ASSESS LABORATORY VITALITY OVER TIME

⇨ KEY–ISSUANCE OF:
DoD
LABORATORIES
ACTION AGENDA
FOR THE 1980's

Much of the DoD laboratories scene is excellent and promotes defense capability. However, to an increasing extent, the quality and vigor of life in the laboratories is diminishing. Restoring the quality of the laboratories is a partnership problem. The LMTF has recommended, and will continue to seek out, steps which are necessary to improve the present and anticipated situation. The OSD and the Military Departments can do much to make the system work better. The laboratories themselves must work even harder to explore ways to make the system more effective. The private sector also shares in closing the gulf. If any element is stereotyped as "good guys" while others are branded as "bad guys" the whole process will suffer.

There are many points of friction; many gaps in understanding. Some are documented; some are rumor. An apparently inexorable tide of bureaucracy and sub-optimized interest seemingly engulfs the situation. Positive action is an imperative. As a step in this direction, the LMTF offers a DoD Laboratories Action Agenda for the 1980's, to encourage in a formal way, imaginative action at every level of the DoD. We must work together more intensively for our common good. Now is the time to act.

DEPARTMENT OF DEFENSE
WASHINGTON, D.C.

STATEMENT OF PRINCIPLES FOR DEPARTMENT OF DEFENSE RESEARCH AND DEVELOPMENT LABORATORIES

The guiding goal for the Defense laboratories is to achieve and maintain a level of technological supremacy that enables the United States to develop, acquire, and maintain military capabilities needed for national security. These Centers-of-Excellence complement universities and industry as a vital resource of the Nation.

OBJECTIVES

Mission

- Ensure the maintenance and improvement of national competence in areas of technology essential to military needs; avoid technological surprise.

- Maintain a continuity of effort, free from excessive commercialization pressure, directed toward the conception and evolution of advanced military materiel.

- Pursue technology concepts through the planning, programming, and budgeting process for support of direct in-house work and for potential contract placement, monitoring, and assessment.

- Provide material acquisition and operating system support.

- Have available a fast-reaction capability to solve critical, immediate technical problems that arise when unexpected operational situations are encountered.

- Stimulate the use of prototypes to mature and exploit U.S. and allied technologies.

- Carry out activities having extraordinary risk or requiring intensive resource investment not available from the private sector.

Operations

- Respond to national defense needs by undertaking actions to—
  - — Achieve timely improvements in materiel systems
  - — Reduce manpower and skill constraints on material performance
  - — Lower production, operation, and support costs for materiel
  - — Extend life of operational systems
- Continue intensive user-developer interfacing to—
  - — Achieve greater sensitivity to potential combat requirements
  - — Integrate technological objectives with materiel readiness, modernization, and sustainability requirements
  - — Evolve effective balance between technology push and requirements pull

- Continue a vigorous partnership with industry and the academic community
- Distribute efforts appropriately across short-, mid-, and long-term horizons
- Participate actively in the overall Defense planning process

Management

Provide laboratory management with the responsibility, authority, and flexibility to manage laboratories and technical programs through use of broad guidelines and without overlapping controls.

- Ensure Competency of *Personnel*
  - — Recognize clearly that the most valuable resources of the laboratories are the capability, skill, and creativity of their personnel
  - — Provide for personnel stability, challenging work, and meaningful incentives
  - — Provide for equal opportunity for development, training, promotion, recognition, and reward
- Upgrade *Facilities and Equipment*
  - — Remove limitations which constrain modernization of laboratories
  - — Promote productivity, energy efficiency, and cost avoidance through policies that modernize facilities and equipment
  - — Base replacement policies on practice that befits the business venture nature of research and development activity
- Provide Effective Procedures for *Procurement and Acquisition*
  - — Provide laboratories with the authority to make procurements and acquisitions in a timely and efficient manner
  - — Ensure technical excellent in performance
- Achieve Continuing *Assessment and Accountability*

The Office of the Secretary of Defense and Military Departments will be jointly responsible for establishing policies and procedures which are conducive to the continuing vitality of the laboratories. Accordingly, periodic evaluations will be conducted to assess the health of the laboratories, the quality and quantity of their contributions, and their performance against the public's legitimate expectations of efficient and effective use of personnel and dollar resources.

SYNOPSES OF SERVICE LABORATORY RESOURCE MANAGEMENT PLANS

In accordance with the memorandum of the Secretary of Defense establishing the DoD laboratory management task force, the Military Departments developed draft plans addressing the management of their laboratory resources. These plans are clear evidence that the services recognize the urgency of maintaining effective laboratories. The plans provided identification of the respective laboratory roles. They reflected deep concern for issues involving manpower size and mix, facility and equipment adequacy, and selected institutional procedures. These plans provide a base for follow-through on the LMTF proposed initiatives.

(See attached Synopses of Army, Navy, and Air Force Plans)

SYNOPSIS OF: ARMY LABORATORIES MANAGEMENT PLAN EXECUTIVE SUMMARY MARCH 1980

The Summary provides top-down insight into the Army's perspectives on management of its laboratories. The Plan contains a host of innovative actions, some on-going, some yet to be addressed, aimed at a single issue—how can/will the Army increase the effectiveness of its manpower and dollar expenditures for laboratories. Clearly, the Army fully recognizes the need to revitalize its laboratories and has developed dynamic approaches for achieving this goal. The Army has an action agenda for the 1980's which is challenging and hard-hitting. As this Plan matures and is implemented in its details, considerable improvement in the vitality of Army laboratories should surely result.

1. The Summary addresses a broad array of factors essential to the effective mission performance of the Army in-house laboratories. It achieves three primary aims:

a. Provides a detailed basis for ensuring a current understanding of the roles of Army laboratories and recognition of their relationship to other Army functions.

b. Summarizes representative issues critical to the vigor of these laboratories.

c. Highlights approaches the Army is using to further intensify management of its laboratories. The Summary is organized to provide top management with focused information in selected areas. Resource breakouts are kept to a minimum. Individual laboratories are not discussed. A fundamental thrust of the Army Plan is to minimize formal report actions with the intent of achieving a living, breathing environment conducive to dynamic planning and vigorous contributions by the laboratories.

2. The Summary clearly provides for Army action to address four concerns:

a. Better ensuring the relevance of the work in the laboratories.

b. Improving facilities and staff.

c. Uplifting the quality of technical leadership and management in the laboratories.

d. Ensuring leadership improvements in the authority and flexibility to effectively manage laboratory resources.

3. A profile of the Army's 34 formally recognized military laboratories is given and their aggregate roles are undisputedly specified. The Summary views issues affecting Army laboratories in three segments:

a. Image

b. Operations

c. Long-term perspectives

Representative problems associated with these segments are itemized.

4. The Army Summary addresses these concerns and issues with two highly action-oriented interrelated thrusts:

a. A perspective structure encompassing the elements critical to effective management of its laboratories by the Army.

b. A participative Research, Development, and Acquisition (RDA) planning process and product to provide general and specific RDA direction to the laboratories through the next two decades and to provide a base against which their individual and collective needs and contributions can be "measured."

5. The perspective structure provides for analyses of the posture of Army laboratories in four areas:

a. Need

b. Capability

c. Performance

d. Planning/Plan

This perspective provides an excellent approach for integrating the Army laboratories with the Total Army.

6. The dominant thrust for achieving this integration is a Long-Range RDA Plan/Investment Strategy. The Summary is supported by an extensive Appendix outlining the Army's actions to achieve this Plan. Review of the Appendix reveals a host of actions directed toward the development and maintenance of a stable Long-Range R-A Plan responsive to total Army capability needs and opportunities. Initial actions have already significantly influenced the Army's POM 82-86 preparation. The first formal Long-Range RDA Plan is targeted to assure responsive Science and Technology, Systems Development, Product Improvement, and Procurement Plans for integration into the POM 83-87 including the Extended Planning Annex for FY88-89. Summary of the Appendix follows.

7. The Army Summary also provides a basis for addressing the four concerns mentioned in paragraph 2 above. This set of over twenty initiatives is focused on specific areas for laboratory improvement and, in the aggregate, they cover the spectrum of matters appropriate for Army attention.

SUMMARY OF APPENDIX ON LONG-RANGE RDA PLANNING

Intensive attention is being given to improving Army long-range RDA investment strategy. Appropriate steps are being taken by the Army Secretariate, DA Staff agencies and offices, and user and developer field organizations. An attitude of urgency and realism is clearly evident.

The dominant thrust is one of mission-orientation. This approach reflects responsiveness to the direction of the Congress, Office of Management and Budget, and Office of the Secretary of Defense, requiring that Army needs and program objectives be expressed in mission terms. The long-range RDA planning actions are being conducted with coordinative attention to major related planning in OSD and the other Military Departments. For example, close contact is being maintained with the Long-Range Research and Investment Planning Program recently initiated by the Deputy Secretary of Defense and the Under Secretary of Defense Research and Engineering.

Although operating on the premise that long-range RDA planning must be conducted as a continuum, direct action has been taken to interface with the PPB System. Significant inputs were integrated with the FY82-86 POM and action is underway to impact POM 83-87.

Two goals have been proposed by the ASA(RDA) as targets for RDA attention:

— Fielded technological equivalence by 1985.

— Fielded technological superiority in the 1990's.

These goals have been well received by the RDA community and are becoming effective driving thrusts. Direct participation from independent sources has been sought and is being provided. For example: the Army Science Board devoted its Summer Study to RDA planning and the American Defense Preparedness Association conducted a two-day symposium for industry and international representatives on Concepts and Requirements for Army Weapon Systems.

Recent emphasis on long-range RDA planning has resulted in important improvements in user-developer interaction on a mission basis. This improved dialogue will better ensure that mission needs are correlated with realistic doctrinal, organizational, and technological alternatives. The planning approach includes the development of Mission Area Analysis and Mission Area Science and Technology Plans by joint user-developer teams. This work is providing improved focus on:

— Battlefield Shortfalls

— Battlefield Opportunities

— Technological Opportunities

Specific actions are being directed to provide a dynamic but stable long-range 15-year RDA planning process with a product in a form usable by top management. Present efforts are strongly oriented to establishing the process, but it is fully recognized that the ultimate goal includes a workable product. To the maximum extent practicable, on-going Phase I MAAs and S&T Plans were available to assist in preparation of the POM 82-86. Phase II MAAs and responsive S&T Plans will be completed prior to the POM 83-87, and integrated into a formal Long-Range RDA Plan.

The Army has identified a shortcoming in its RDA process and taken corrective action. Until recently RDTE funds could not be expended for Product Improvement until a system was type classified. Action has been taken to remove this constraint and to initiate a concept of Block Design Product Improvements which offers the opportunity to field systems with overlap and thereby achieve technology insertion and better protection of the material investment.

There is good recognition of the deficiencies in the status of current long-range RDA planning and assertive action to institute steps to achieve the necessary levels of improvement. The Army laboratory communities (material, medical, engineer, and personnel) are all working to provide imaginative inputs to the Long-Range RDA Plan and to respond to the work thrusts resulting from the long-range planning process.

NAVY LABORATORY RESOURCE PLAN
DRAFT, MARCH 1980
A SYNOPSIS

The Navy Laboratory Resources Plan covers the 8 Chief of Naval Material-Commended Laboratories, the Naval Research Laboratory, the Naval Oceanographic Research and Development Activity, and the Naval Civil Engineering Laboratory. These are the major Navy Laboratories. Not covered in this plan are Navy Medical Laboratories and RDTE Activities that are attached to the Naval Material Command Systems Commands. The Navy Laboratories covered in this plan have the following characteristics:

— Full-spectrum laboratories (6.1) — Procurement-Operations & Maintenance

— Industrially funded

— Preponderantly civilian work force

— Relatively large (greater than 1000 people)

— Strong orientation to naval platform and mission

— 70% total (about 50% tech base) funds are passed through to industrial contractors

— Major components of the Navy Acquisition Process

— Federation of closely cooperating activities

The Navy Laboratory Resources Plan details the Navy's corporate approach to effective use of available R&D resources. The greatest common concern in the Navy Laboratories centers about the problems of maintaining the technical excellence and diverse capabilities under conditions that make it increasingly difficult to recruit and retain highly qualified people.

The plan summarizes recent technical achievements of the Navy Laboratories in tech. base, development, procurement, and fleet support categories.

Roles, missions, and management of Navy R&D Centers.

— Continually assessed in view of continuing changing environment

— Anticipate long-range impact of Federal Policies (A-76, A-109)

  — Transfer of additional work to private sector

  — Industrial involvement at early stages of acquisition process

— Objective for Navy to remain a sophisticated buyer, to continue to improve management of Navy acquisition, to maintain a quick-reaction RDTE capability

— Above requires strong, in-house, hands-on R&D effort to attract competent scientists and engineers

— There are management problems that are associated with initiation, termination, and transfer of technological effort, e.g., tech. base to development

— Navy laboratories are aggressively implementing Senior Executive Service and CSRA-78 and are oriented to management by objectives

Technology base is vital to systems acquisition and support; in-house capability in the Navy is eroding—coupled with the shift of laboratory manpower to non tech. base, and non-RDTE funded efforts. Reversing these trends is essential to maintaining the integrity and vitality of the Navy laboratories.

Navy Laboratory Centers are providing more support to Program Management Offices in System Development. Efforts are being aligned with the technology base so as to provide efficient transition up the development chain. Such alignments reverse an earlier trend to minimize the laboratory contribution in Systems Development.

Achieving proper balance among the tech. base, system acquisition, and fleet support remains a challege to management at the individual laboratories—a challenge that is underscored by the erosion of the tech. base work mentioned above.

The prospect of real growth in Navy R&D presents something of a dilemma to Navy Laboratory managers. Because of personnel ceilings it has become necessary to rely increasingly on industry to absorb additional laboratory work loads. Further increases in contracting out could result in changing the basic characteristic of laboratory operations with the attendant losses of competent scientists and engineers.

Industrial funding exacerbates the rate at which imbalances among the various categories of work—tech base, advanced development, fleet support, etc.—arise. The reexamination of the applicability of current industrial funding practice is very important to the Navy Laboratory System.

The tendency toward centralization in procurement, contracting, and even in providing automatic data processing equipment has resulted in excessive time and effort in justifying and defending new ADP procurement and applications. All this is in the face of the repeated demonstrated fact that productivity of R&D centers can be further increased by new and imaginative uses of the latest available ADP. The Navy has prepared a Five Year ADP Plan.

PERSONNEL RESOURCES

— Most important single class of resource

— Predominant concern

— Serious erosion of morale and of quality professional work force results from recent history of freezes, ceilings, reductions in force, and other factors tending toward instability.

— The NOSC-NWC Personnel Management Demonstration Project that begins in 1980 is a major initiative in using new approaches to job classification assignments, pay, and incentives to bring about major improvements in the ability to recruit, retain, and utilize high quality professionals.

— Navy R&D Centers are attempting to improve utilization of military personnel although, since their quest is for operationally experienced R&D-oriented project personnel, the R&D Centers are in competition with each other.

This is the Navy Laboratory Resource Management Plan response to the DoD Laboratory Task Force Initiatives to Resource Barriers to Effective Management:

— Working Groups of the DoD Laboratory Management Task Force identified issues in the various fields of personnel, procurement and acquisition, and military construction and facilities. The Navy Plan comments on these issues have been summarized above.

— The Navy Plan amplifies and addresses the issues and sets out conclusions, recommendations, and action alternatives to mitigate the problems that are identified.

— The Navy members of the DoD Laboratory Management Task Force Working Group are working with the Army, Air Force, and OSD counterparts to revise directives and authorities where applicable to prevent corrective actions.

— Through the Navy Laboratory Corporate Plan the Director of Navy Laboratories promulgates corporate goals, objectives, and initiatives on an annual basis.

— Management profiles on the component Navy Laboratories are provided in the Navy Laboratory Resource Plan.

AIR FORCE LABORATORY RESOURCE PLAN
31 MARCH 1980
A SYNOPSIS

- The Air Force Laboratory Resource Plan projects laboratory programs and the resources necessary for program implementation.

- Noting that availability of resources is a necessary but not sufficient condition for program success, the Air Force Laboratory Resource Plan describes briefly the effects that some constraints and barriers to effective laboratory management, that have been addressed by the DoD Laboratory Management Task Force, are having on the Air Force in the performance of the technology mission, and on the vitality of the laboratories.

- The Air Force Laboratories receive about 75% of their funding from the Director of Science and Technology at Air Force Systems Command Headquarters. Laboratory programs are organized along Technology Program Objective lines. The Air Force plans for 10% real growth each year in basic research and 5% real growth per year in exploratory development. Military personnel comprise about 30% of the technical work force—a much higher fraction than is found in the Army and Navy Laboratories. Salaries for military personnel are not included in laboratory budgets; but civilian salaries are. Air Force Laboratories are not industrially funded.

MANAGEMENT

Constraint Effects on the Air Force Laboratories (categories are those of the DoD Laboratory Management Task Force):

- Personnel
  - — Civilian ceilings are acceptable if somewhat constraining
  - — Air Force Laboratories operate under stable personnel authorizations
  - — Salary comparability a concern—Air Force Laboratories affected by salary structure and its resultant effect on recruitment and retention of quality people
  - — Low promotion potential contributes to loss of work force quality
  - — Must create personnel environment comparable to that existing in other R&D activities
- Military Construction and Facilities
  - — Obsolescence of facilities and equipment and the need for new research capabilities present increasingly severe problems for the Air Force Laboratories
  - — Changing technology missions of Air Force Laboratories not adequately supported
  - — Corrective action required to prevent unacceptable erosion of Air Force Laboratory capabilities
- Procurement and Acquisition
  - — Thresholds for requirement of Secretarial Determinations and Findings (D + F) and for imprest funds overly restrictive due to inflation
  - — Results in increased delays and paperwork

— Purchase from imprest funds similarly affected

— Procurement and acquisition problems in laboratories exacerbated by

  — Absence of dedicated R&D buyers

  — Imposition of standard supply procedures for R&D purchase orders

— Above all present barriers to effective management of laboratory programs.

THE SECRETARY OF DEFENSE
Washington, D.C. 20301

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING
ASSISTANT SECRETARY OF DEFENSE (COMPTROLLER)
ASSISTANT SECRETARY OF DEFENSE (MANPOWER, RESERVE AFFAIRS AND LOGISTICS)
DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

SUBJECT: DoD Laboratory Management

The quantity and quality of military systems being fielded by the Soviets demand improved management of our scientific and technological resources, to expand our technological options.

Last year, the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology) initiated an inter-Service review, to identify institutional barriers on the DoD Laboratories' ability to accomplish their missions. The review identified a number of barriers to effective laboratory management that limit the efficient use of our resources.

I would like each Service to develop a laboratory resources plan for each lab, that provides for increased management authority to utilize more effectively personnel and fiscal resources. Plan should include a means for the continuing evaluation of managerial use of the flexibility and latitude provided. These plans should be completed by the end of March, 1980 and submitted to the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology) for approval. Upon approval, unnecessary administrative restrictions upon the exercise of managerial discretion should be removed from the laboratory operations. I intend this action to establish reasonable boundaries for laboratory management's discretionary use of resources.

I am establishing a DoD Laboratory Management Task Force, chaired by the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology), to oversee our continuing efforts toward improving the vitality of our laboratories. An important function of this Task Force will be to review and approve the Service plans and take the necessary follow-up action to achieve our goals in this vital area. I would like each addressee to nominate a principal and at least one working level representative to the Task Force by mid-October, 1979.

Harold Brown

Attachment

DOD LABORATORY MANAGEMENT TASK FORCE (LMTF) PARTICIPANTS

OFFICE SECRETARY OF DEFENSE

Dr. Arden Bement, DUSDE(R&AT)
Mr. Albert Bottoms, DUSDE(R&AT)
Ms. Kathleen Carpenter, DASC(MRAL)EO
Dr. George Contos, OSD(MRA&L)
Mr. Nelson Eaton, OSD Comptroller
COL. Tenho Hukkala, OUSDRE(R&AT)
Dr. George Millburn, OUSDRE(R&AT)
Mr. Gordon Sigman, DARPA/TTO
Dr. James Tegnelia, DARPA/TTO
Mr. Charles Weatherholt, OASD(CPP)

ARMY

Dr. Eugene Yore, OASA(RDA)
MAJOR Kearney Crissman, DAMA-PPR-P
Mr. James Spates, DAMA-ARZ-C
Dr. Robert Wiseman, DARCOM-DRC-DMD/ST

NAVY

Dr. James Probus, DNL, MAT 08L
Dr. Alan Berman, TD, NRL
Mr. Ken Boyd, Code D2B, NSWC
Mr. Walter Clearwaters, Code 20, NOSC
Dr. Kenneth Lobb, TD, NADC
Dr. Charles Schoman, Code 011, DTNSRDC
Mr. Stuart Simon, Code 702, NADC
Mr. George Swiggum, Code MAT08L31

AIR FORCE

Dr. Walter Beam, OASAF(RD&L)
LTCOL. Hugh Bainter, AFSC/DLZ
COL. Thomas Ferguson, AFSC/DL
Dr. Bernard Kulp, AFSC/DLZ
Mr. Robert Supp, AFWAL/PO
BG. Brien Ward, Director S&T, AFSC

Distribution List:

OSD

Assistant Secretary of Defense (Comptroller

Assistant Secretary of Defense
(Manpower, Reserve Affairs & Logistics)

Defense Advanced Research Projects Agency

Defense Science Board

General Counsel
Office of the Secretary of Defense

Assistant to the Secretary of Defense
for Legislative Affairs

Deputy Assistant Secretary of Defense
(Manpower, Reserve Affairs & Logistics)
Equal Opportunity

ARMY

Assistant Secretary of the Army
(Research, Development & Acquisition)

Deputy Chief of Staff
(Research, Development & Acquisition)

Director of Army Research

Assistant Deputy Commanding General for
Materiel Development/Science & Technology

Commander
US Army Research Institute for
Behavioral and Social Sciences

Deputy Chief of Staff for Personnel
Research and Studies Office

NAVY

Assistant Secretary of the Navy
(Research, Engineering and Systems)

Chief of Naval Material

Deputy Chief of Naval Material
For Acquisition

Assistant Deputy Chief of Naval Material
For Laboratory Management

Assistant Deputy Chief of Naval Material

Chief Scientist,
Office of the Assistant Deputy
Chief of Naval Material
Chief of Naval Operations
Program Planning Office
Studies Management Branch (OP 966)

AIR FORCE

Assistant Secretary of the Air Force

Commanding General
Air Force Systems Command

Chairman
Scientific Advisory Board

Deputy Chief of Staff
(Research, Development & Acquisiton)

Chief Scientist, AFSC

Technical Director, AFOSR

Director of Laboratories, AFSC

Commander
US Army Material Development and Readiness Command

Commander
US Army Research Office

Director
US Army Materials and Mechanics Research Center

Director
US Army Human Engineering Laboratory

Commander
US Army Armament R&D Command

Director
US Army Ballistic Research Laboratory

Commander
Chemical Systems Laboratory

Commander
Large Caliber Weapons Systems Laboratory

Commander
Fire Control and Small Caliber Weapons Systems Laboratory

Commander
US Army Aviation R&D Command

Director
US Army Aviation Research and Technology Laboratories

Director
Aeromechanics Laboratory (USARTL)

Director
Applied Technology Laboratory (USARTL)

Director
Propulsion Laboratory (USARTL)

Director
Structures Laboratory (USARTL)

Commander
US Army Avionics R&D Activity

Commander
US Army Aviation Engineering Flight Activity

Commander
US Army Communications R&D Command

Commander
US Army Electronics R&D Command

Commander/Director
Atmospheric Sciences Laboratory

Commander
Combat Surveillance and Target Acquisition Laboratory

Director
Electronics Technology & Devices Laboratory

Director
Electronics Warfare Laboratory

Commander
Harry Diamond Laboratories

Director
Night Vision and Electro-Optics Laboratory

Director
Signals Warfare Laboratory

Commander
US Army Mobility Equipment R&D Command

Commander
US Army Missile Command

Commander
US Army Natick R&D Command
Commander
US Army Tank-Automotive R&D Command

Office, Chief of Engineers
Research & Development Office

Commander
US Army Construction Engineering Research Laboratory

Commander
US Army Cold Regions Research and Engineering Laboratory

Commander
US Army Engineer Topographic Laboratories

Commander
US Army Engineering Waterways Experiment Station

Commander
US Army Medical R&D Command

US Army Aeromedical Research Laboratory

US Army Institute of Dental Research

US Army Institute of Surgical Research

Letterman Institute of Army Research

US Army Medical Bioengineering R&D Laboratory

US Army Medical Research
Institute of Infectious Diseases

US Army Research Institute of Environmental Medicine

Walter Reed Army Institute of Research

US Army Biomedical Laboratory

Commander
Naval Ocean Systems Center

Commanding Officer
Naval Underwater Systems Center

Commanding Officer
Navy Personnel Research and Development Center

Commander
David W. Taylor Naval Ship Research and Development Center

Commanding Officer
Naval Research Laboratory

Commander
Naval Weapons Center
Commander
Naval Surface Weapons Center

Commanding Officer
Naval Coastal Systems Center

Commander
Naval Air Development Center

Chief of Naval Research

Director
Research, Development, Test and Evaluation
Chief of Naval Operations

Commanding Officer
Naval Air Engineering Center

Commanding Officer
Naval Air Propulsion Test Center

Commanding Officer
Naval Environmental Prediction Research Facility

Commander
Pacific Missile Test Center

Commanding Officer
Naval Weapons Evaluation Facility

Officer-in-Charge
Civil Engineering Laboratory
Naval Construction Battalion Center

Commanding Officer
Naval Biosciences Laboratory

National Academy of Sciences

Commander
Naval Air Test Center

Commanding Officer
Naval Ocean Research and Development Activity

Commanding Officer
Naval Ordnance Missile Test Facility

Commanding Officer
Naval Explosive Ordnance Disposal Facility

Commanding Officer
U.S. Naval Medical Research
Unit No. 3

Commanding Officer
Naval Aerospace Medical Research Laboratory

Commanding Officer
Naval Health Research Center

Commanding Officer
Naval Medical Research Institute

Commanding Officer
Naval Dental Research Institute

Rome Air Development Center

Avionics Laboratory

Air Force Materials Laboratory

Air Force Geophysics Laboratory

USAF School of Aerospace Medicine

Aerospace Medical Research Lab

Human Resources Laboratory

Air Force Weapons Laboratory

Air Force Rocket Propulsion Laboratory

Aero Propulsion Laboratory

Frank J. Seiler Research Laboratory

Armament Development and Test Center (ADTC)

Air Force Flight Dynamics Laboratory

USDRE INDEPENDENT REVIEW OF DoD LABORATORIES

22 March 1982

Prepared by:
Dr. Robert J. Hermann

Prepared for:
Under Secretary for Defense Research and Engineering

TABLE OF CONTENTS

Section		Page
EXECUTIVE SUMMARY		iv
1	INTRODUCTION	1-1
2	BACKGROUND	2-1
3	FINDINGS	3-1
	3.1 The Technology Environment Surrounding the Laboratories has Changed	3-1
	3.2 The Need for and Utility of the Laboratories and R/D Centers	3-2
	3.3 There Really is a Laboratory Problem	3-3
	3.4 There is a Disconnect Between the Laboratories and the Operating Forces	3-4
	3.5 Everyone Feels Cheated by the Process	3-7
	3.6 The Time is Ripe for Improving DoD Laboratory and University Relationships	3-8
	3.7 There are new Technologies and Technology Based Operational Functions Which Need Special Attention	3-9
4	RECOMMENDATIONS	4-1
	4.1 Upgrade Personnel Practices	4-3
	4.1.1 Expand NWC/NOSC Demonstration	4-4
	4.1.2 Resurrect PL-313-Like Positions	4-5
	4.1.3 Reduce Administrative Impact of Civil Service Reform Act	4-5
	4.1.4 Work on a Differential Pay System	4-7
	4.1.5 Provide Tenure for Laboratory and Technical Directors	4-8
	4.1.6 Expand Student Support Programs	4-8
	4.1.7 Provide Consistent DoD Policy	4-9

TABLE OF CONTENTS (Continued)

Section		Page
4.2	Streamline Procurement Practices	4-10
4.2.1	Improve Procedures for Small Contracts (Less Than 500K)	4-10
4.2.2	Relax Technology Base Obligation Constraints	4-11
4.2.3	Select Study Group to Review Small Procurements	4-11
4.3	Modestly Increase the Rate of Modernization of Facilities and Equipment	4-12
4.3.1	Support LMTF Recommendation on Facilities	4-12
4.3.2	Support LMTF Recommendation on Equipment	4-13
4.4	Improve the DoD/University Relationships	4-13
4.4.1	Support DSB Recommendations to Increase University Support by Defense with Associated Equipment Modernization	4-13
4.4.2	Support DSB Recommendation to Establish New S&E Fellowships	4-14
4.4.3	Continue the Dialogue Regarding the Security of Intellectual Property	4-14
4.4.4	Expand Student Utilization Programs	4-15
4.4.5	Extablish a Two Year Undergraduate Program for Civilian Employment Patterned after the ROTC	4-16
4.4.6	Increase DoD and University Emphasis on Industrial Education Related to Logistics and Manufacturing	4-16
4.4.7	Establish Defense Centers of Excellence with Universities in New Technology Areas	4-16

TABLE OF CONTENTS (Continued)

Section		Page
4.5	Establish External Advisory Groups for Each Laboratory	4-17
4.6	Establish an Effectiveness Review Process for the Laboratories	4-18
4.7	Improve Industrial Visibility of Laboratory Activities	4-19
4.8	Develop a Formal Process for an Operational Concept Projection and Application	4-20
4.9	Expand Laboratory Relationships with Operational Forces	4-23
4.10	Strengthen the Services Logistics R&D Programs	4-26
4.11	Expand Technology Demonstrations	4-27
4.12	Establish a Defense Center for Simulation Research and Development	4-29
4.13	Establish a New Center for Micro-Electronics and Computer Science	4-33
4.14	Form an Electronic Warfare Techniques Development Center	4-36
4.15	Establish a Formal Command and Control Research Program and Center	4-38

Appendices

USDRE Memo: Review of DoD Laboratories	A-1
Study Group Participants	A-2
Industry Advisory Group for Review of DoD Laboratories	A-4
Industrial Association's Participants	A-5
People Interviewed	A-7
U.S. Army Laboratories/Facilities Visited	A-9
U.S. Air Force Laboratories/Facilities Visited	A-10
U.S. Navy Laboratories/Facilities Visited	A-11

EXECUTIVE SUMMARY

On 3 September 1981, Dr. Richard Delauer, Under Secretary of Defense for Research and Engineering, established a review of Department of Defense laboratories. This review was undertaken by Dr. Robert Hermann, under the direction of Dr. Robert Cooper, with the assistance of representatives of the Army, Navy, Air Force and DARPA.

The study team found:

- There is indeed a strong and continuing need for the DoD to maintain the Laboratories and R&D centers.

- Much good work is being done in the laboratories and technology created by the laboratories continues to make its way into the operating forces.

- There really are several fundamental problems involving laboratory performance and laboratory relationships with the ultimate user community.

- There exists a disconnect between the laboratories and the Operating Forces which exacerbates the problem of technology transition to the field.

- Industry, the laboratories, and the user community all feel cheated by the existing process.

- The time is ripe for improving the DoD/University R&D connection.

- There are new technology opportunities and technology based operational functions, which have evolved in recent years, which require special DoD attention to realize the maximum benefit.

- The technology environment surrounding the laboratories has dramatically changed in recent years, which requires that DoD and the Services reassess the laboratories' roles and missions.

The study team recommends:

- That the USDRE initiate action to upgrade laboratory personnel practices. Special recommendations are included in the report.

- That the USDRE support initiatives to streamline the procurement process, which is viewed as a major deterrent to the laboratories' efficient operation and innovation process.

- That the DoD modestly increase the rate of modernization of facilities ($70M per year per Service for the next 10 years) and equipment ($25-30M, per service per year for the next 10 years).

- That the USDRE support the goal of improving the DoD/University connection (six individual recommendations are included).

- That the USDRE support the establishment of an External Advisory group for each laboratory.

- That the USDRE support the establishment of an outside, expert review process which would assess each laboratory's effectiveness every 3-5 years.

- That the USDRE initiate appropriate action to improve industry's visibility of laboratory activities.

- That the DoD undertake the initiation of a formal process to develop operational concept projections to provide scenarios of future military operations. This document should unify the various Service perceptions, and then be used by the laboratory community to guide their respective technology developments.

- That the USDRE undertake a new approach to coupling the laboratories with the Operational Forces by providing the Unified and Specified Commands and subordinate component commands with modestly sized technical staffs, drawn from the DoD laboratories.

- That the USDRE task each military department to establish a formal "Logistics R&D Program." It is perceived that this area of R&D consistently receives inadequate attention by the Services.

- That the USDRE support the expansion of critical demonstration programs by providing the ASD(RT) with a $300-400M set-aside.

- That the USDRE support the establishment of a Defense Center for Research in Simulation Techniques and Technologies.

- That the USDRE form a special task group to examine the optimum mechanism for establishing a new Center for Micro-electronics and Computer Sciences.

- That the USDRE support the expansion of the Joint Electronic Warfare Center (JEWC) in San Antonio, TX, to strengthen the DoD capability to develop and apply new electronic warfare techniques; to focus on joint and combined technology-operational techniques; and to conduct test and evaluation.

- That the USDRE support the establishment of a formal Command and Control Research Program and Center, which is consistent with the DSB report of 1978 on C^3 acquisition.

Further amplification of each of the above recommendations is included in the report.

57-279 O - 87 - 40

Section 1
INTRODUCTION

On 3 September 1981, Dr. Richard DeLauer, under Secretary of Defense for Research and Engineering, established a review of Department of Defense laboratories. This review was undertaken by Dr. Robert Hermann under the direction of Dr. Robert Cooper with the assistance of representatives of the Army, Navy, Air Force and DARPA.

During the course of the review, 28 laboratories, R/D centers, and related organizations were visited; a host of industry and government officials were interviewed; and four major industrial associations (ADPA, AIA, EIA, NSIA) were consulted (see Appendix, pages 4, 5, and 7). In addition, an industrial advisory group was formed, in part from the 1981 DSB Task Force on the DoD Technology Base, to advise, critique, and comment on the final report and its development.

Section 2
BACKGROUND

The "DoD Laboratories" are a set of 73 laboratories, research and development centers, research institutes and development boards which include 60,000 people, $6 billion in capital facilities and equipment, and 1981 expenditures of more than $5 billion for research and development effort.

An anxiety exists in the minds of many who observe, work with, and work in the laboratories and R/D centers about the health and future of these activities. They are concerned with a variety of issues and trends which seem to dominate the present circumstances:

- Many laboratories have had consistent difficulty in recruiting new, young engineers at the GS-5/7 levels, and also in retaining the most competent and experienced scientists and engineers. The salary constraints of government employment, escalating industry salaries, increasing bureaucratic administrative burdens in the laboratories, and other factors are causing a loss of work force competence.

- The procurement policies, procedures, and practices forced on the laboratories by legislation and regulation cause an excessive investment in non-productive activities and are so burdensome and counter-productive that innovation is greatly constrained.

- The facilities and, in many cases, the lab equipment are outdated, inefficient, and in need of replacement.

- The laboratories seem to be working on the wrong problem from either viewpoint of technology opportunities or operational needs. Also their ability to adjust and respond to new technology developments seems unduly slow.

- It is evident to all observers that the process of technology transition to operational forces is not working well and some (but surely not most) of the blame is levied on the laboratories.

- The relationship between the DoD and our universities could be measurably improved to the advantage of both sectors.

These concerns have stimulated several previous laboratory reviews which have resulted in relatively consistent conclusions and recommendations:

- The laboratories are essential.
- They need to be better.
- Their personnel practices must be upgraded.
- Their procurement practices must be streamlined.
- Their facilities and equipment need to be kept up to date.
- Their relationships with universities should be improved.

Many of these recommendations have been acted upon with varying degrees of completeness but there is broad agreement that more needs to be done to correct the deficiencies in the laboratories and the processes which surround them.

With this background, the present review was initiated.

Section 3
FINDINGS

3.1 THE TECHNOLOGY ENVIRONMENT SURROUNDING THE LABORATORIES HAS CHANGED

The technology environment in which the laboratories find themselves today has substantially changed and their role and mode of operation has changed. It must continue to change with the environment, as must our collective judgment about the roles and limitations of these centers.

Some of the anxiety about the health of the laboratories comes from those who compare today's laboratories with the performance and influence of the labs of past generations. There may be some merit in making such a comparison but for the most part it is not appropriate. The technology environment surrounding the laboratory has changed profoundly in the past two decades. There has been a massive proliferation of new technologies which have relevance to defense. The technologies have infused the civil and commerical sector in an all-pervasive way causing, among other things, great competition for skilled personnel and a substantial reduction in the leverage DoD can use in the high technology market place. Technology options are now wider and the technical questions are more complex; in part because of the increased number of functions being built into systems, and in part because of the phenomenal increase in parts count, cost and development time.

The relative position of the U.S. in technology has changed. In the early years after World War II, the U.S. had

an overwhelming superiority in both the technology and industrial base. Since then, Western Europe and Japan have made remarkable strides and now challenge the U.S position in many areas. Within the U.S., the Defense Department no longer dominates the high technology market as it did in the early 1960's. These factors change many aspects of laboratory life including the type and range of personnel skills needed, the relationship with Program Managers and Commands, and with industry.

3.2 THE NEED FOR AND UTILITY OF THE LABORATORIES AND R/D CENTERS

Most observers and participants in the DoD acquisition process agree that the DoD does need a strong and viable set of R/D laboratories and centers such as those now in existence. There are varying opinions as to which are essential, what the fundamental problems confronting these institutions are, how they should behave, and what corrective measures should be taken. However, there is nearly universal recognition that:

- Good work has been and is being done by the labs through in-house work and sponsored efforts in industry.

- Much of this work has resulted or will result in the transition of new technology into systems now in use in our operational forces.

- Most of the functions assigned to these centers cannot reasonably be transferred to private industry.

3.3 THERE REALLY IS A LABORATORY PROBLEM

These positive assessments are clouded by the concern by many that we may not be getting our moneys worth. For the dollars, personnel, investment, and management attention involved:

- Too little new technology finds its way to the operating forces and, while the laboratories are not the primary agents responsible, they can play an important role in improving this process.

- The government does not seem to be a very smart buyer. Again, the Systems Commands and major Program Managers are primarily responsible but improved laboratories with better procedures for their participation would be a positive factor.

- The quality of laboratory scientific and engineering personnel is eroding.

- Bureaucratic procedures and perhaps an aging work force are suppressing the innovation necessary to advance the technology of these times.

After reviewing past reports, visiting nearly one-third of the laboratories, and listening to the views and recommendations of industrial managers and associations, the judgment clearly emerges that there are several fundamental problems involved with the laboratory performance and the relationship between the laboratories and the ultimate users of their efforts. While the internal situation of the labs should not be judged as disastrous yet, it seems clear that

if the business of the laboratories were to continue to be conducted in the future as it has been in the past 5-10 years, the health and viability of the laboratories and their role in the whole DoD research, development, and acquisition process will be jeopardized.

Many who work in the laboratories agree with the assessment that we are not getting our money's worth. They are profoundly frustrated by the manifold constraints in their personnel system, the procurement procedures, and the programming and budgeting process.

Thus, while the laboratories are essential, it is imperative that changes in the process be made to correct both their real and apparent deficiencies. Either the real deficiencies or those which are perceived could severely damage the system if left unchecked for very long.

Prior studies have also reflected these concerns and, to the extent corrective measures have not been implemented the situation has deteriorated. The urgency is now greater than ever; the problems which caused concern in the past have grown, the technology competition has increased, and our operational posture has become more important.

3.4 THERE IS A DISCONNECT BETWEEN THE LABORATORIES AND THE OPERATING FORCES

Perhaps more serious than the problem of the internal health of the laboratories and R/D centers is the relationship of the acquistion process to the operational forces and the general problem of transitioning the products

of the labs into operating systems which are affordable, reliable, and supportable and fit into realistic operational concepts. This issue is dominated by the broader acquisition management process primarily involving Program Managers which has received very high level attention. Deputy Secretary of Defense Carlucci has originated a set of 32 initiatives aimed at improving the acquisition process. However, the laboratories are also an important element of this process and can be an important instrument in improving the transition of new technology.

We have not effectively applied many of the new and potentially high leverage technologies which have been available over the past two decades. A cursory review of the forces and systems now in the field and being fielded will lead to the judgment that we have been ineffective at both translating technology into a fielded system and adopting operational doctrine and concepts to take advantage of modern technologies and techniques.

We have now suffered many years of the consequences of fielding complex modern systems based on high technology and design rules driven by technical performance. There has been a systematic disregard of issues such as:

- Whether we can afford to buy enough of the item to gain the operational leverage which formed the basis for the investment.

- Whether the system will be reliable enough to be available when needed while avoiding unusual maintenance cost and impact.

- Can the system be maintained by the anticipated maintenance work force without unreasonable cost or impact on the operational availability of the system.

- Will the logistics concepts, procedures, and personnel be adequate to maintain the system's operational availability.

The program managers and supporting laboratories need to make some changes in approach to reverse this situation.

The laboratories have great difficulty understanding and representing what will be needed by operational forces. Industry observes this as an annoying lack of coherence and direction on the part of the government which creates inefficiency through lack of consistency. Laboratory personnel themselves are frustrated at not being able to decipher what operational authorities need through what is displayed or expressed to the labs. The operational commands need a better relationship with both the labs and the system commands.

Functions which are integrated with and imbedded in the command structure such as communications, command and control, electronic warfare, and the battlefield application of intelligence have suffered through lack of adequate means of technology application. These functions demand not only the ability to rapidly adapt to new technology but also the need for combined operational-technical competence in integrating these new technologies into operational doctrine and concepts. The laboratories are organized along the lines of engineering functions, platforms, or commodities and are not well equipped to address these problems.

3.5 EVERYONE FEELS CHEATED BY THE PROCESS

In general, all participants feel cheated by the process through which the laboratories must make their contribution. Industry is convinced that it could do so much more for the defense effort if the laboratories (as well as others) could consistently represent operational needs and could use reasonable procurement procedures in acquiring their goods and services. They also resent what they feel is unfair competition by the laboratories from a privileged position. Laboratory personnel are frustrated by a nearly unbelievable set of personnel procedures, administrative burdens, and excessive procurement process constraints. Examples abound such as budgetary instability and several levels of reviews, audits, and inspections. They are further troubled by the inability to obtain consistent direction about real operational needs and resource levels. They object to what they see as overly conservative system Program Managers who are unwilling to use their technology products. The Program Managers are unhappy with the lack of realism, insensitivity to cost, and schedule demands on them displayed by their laboratory counterparts. The record of major system cost and schedule overruns provides some justification for this attitude. The operational commands are disappointed and cynical about the application of new technology to their problems as a result of years of observing that it takes an inordinate amount of time to get new technology into fielded systems, and when fielded they are often unreliable, hard to maintain, and difficult to support. Finally, informed citizens feel cheated by the lack of both efficiency and effectiveness of this application of their substantial tax dollars which reflects into the political active assessment of "waste in the DoD."

Those responsible for managing the acquisition process both in the executive branch and in congress must take steps to correct this destructive and seemingly pervasive attitude. It is an injustice to the nation and to those whose talent and energy are applied to the problem of national defense.

3.6 THE TIME IS RIPE FOR IMPROVING DoD LABORATORY AND UNIVERSITY RELATIONSHIPS

The university and DoD laboratory relationship has waxed and waned over the past 30 years with perhaps the worst of times being represented by the late sixties and early seventies. The relationship was obviously strained because of reaction to the Vietnam War, but also because a decreasing amount of DoD funding was going to the academic community.

Since the mid-seventies the situation has improved, with DoD and the university community acting in concert once again. Funding for university research has not reached the levels of the early seventies, but the relationship or cooperation for the mutual benefit of universities and the DoD is improving.

However, the nation now faces a severe shortage of technically trained people. This is reflected in the lack of graduates for government and industry, university faculty, graduate students, and in the lack of facilities to do outstanding research. Both the DoD and the universities should have a high motivation to jointly help to solve their somewhat separate problems. Much of the apathy and antipathy of the past decade is past and both the need and opportunity to solve some of these problems together seems to exist.

This problem is being addressed by several study groups on a nation wide basis. In particular, the Defense Science Board (DSB) has just issued a report entitled "University Responsiveness to National Security Requirements."

3.7 THERE ARE NEW TECHNOLOGIES AND TECHNOLOGY BASED OPERATIONAL FUNCTIONS WHICH NEED SPECIAL ATTENTION

As new technologies have emerged with increasing rapidity, the existing lab structure and work force have not been able to keep up with and organize to apply them to defense problems. Further, the gradual infusion of new technologies into U.S., allied, and opposing forces has created new operational situations and opportunities which require a combination of operational and technical competences to exploit. There are a few specific areas of new technology opportunities which require extraordinary management attention. Those recommended for specific attention now are:

- Micro-electronics
- Software Research and Development
- Artificial/Machine Intelligence
- Electronic Warfare
- Command and Control

Each is treated in more detail in the section covering recommended actions.

Section 4
RECOMMENDATIONS

To help correct some of the deficiencies noted above, and to respond to the technical and operational challenges which face the Department of Defense, several actions are recommended. These initiatives are listed below, and outlined in more detail in the following pages.

1. Upgrade Personnel Practices
2. Streamline Procurement Practices
3. Modestly Increase the Rate of Modernization of Facilities and Equipment
4. Improve University Relationships
5. Establish External Advisory Groups for the Laboratories
6. Establish an Effectiveness Review Process for the Laboratories
7. Improve Industrial Visibility of Laboratory Activities
8. Develop an Operational Concept Basis for Guiding Technology Development
9. Expand Laboratory Relationships with Operational Forces
10. Strengthen Service Logistics R/D Programs
11. Expand Critical Technology Demonstrations
12. Establish a Defense Center for Research in Simulation
13. Establish a New Center for Micro-electronics and Computer Science
14. Form an Electronic Warfare Techniques Development Center
15. Establish a Formal Command and Control Research Program and Center

It is difficult to order these initiatives in a single, declining order of importance. However, they can be grouped as follows:

- The first seven topics are aimed primarily at the internal health of the laboratory system as an operating technical organization and its relationship to industry.

- The second four topics are aimed at the relationship of the laboratories to operational forces and the technology transition process.

- The final four topics address possible initiatives in new technical/operational disciplines.

The above initiatives can be evaluated and prioritized against several criteria.

The greatest return on management energy invested will result from improving our ability to transition technology into operational capability. Thus, improving the lab/operating command connection, generating an operational projection for technology management, an increased technology demonstration program, and logistics research and development investments have high leverage. However, several other actions aimed at other primary objectives will help in this respect also. For example; an improved simulation capability and closer relationship to training operational commands could markedly improve the relevance of lab activities;

inclusion of command representatives in the technical review process will help; and the initiatives in EW, C^3, and Logistics will generate useful mechanisms for transition of technology.

It is also true that without sustained quality and competence in the laboratories, a better connection to the Systems Commands and Program Managers will not be of much value. Therefore, improving the personnel practices of the laboratory process is absolutely essential. Of lesser but still profound importance are the issues of: a quality review process, procurement practices, facilities, and general purpose equipment.

Finally, the need to generate new energy and innovation in the technical areas of micro-electronics and computer science, simulation, logistics, electronic warfare and command and control cannot truly be evaluated as secondary. They are needed because of the essential nature of these disciplines and the dependence of our defense posture on our ability to translate their leverage to our operational forces. They are also needed to demonstrate to ourselves as well as others that we have the capacity to change and adapt our institutions and our programs to new situations.

4.1 UPGRADE PERSONNEL PRACTICES

An absolute prerequisite for the maintenance of effective laboratories is a competent work force. The personnel practices of the past 5-10 years have caused an

extensive erosion in the competence, morale, and effectiveness of this work force and, if continued, would lead to the decline of the laboratory system.

Some very important changes have already been initiated with congressional action to raise the pay cap and relax the limitation on high grades. These will provide some much-needed flexibility to laboratory managers to promote good young engineers who have waited at lower grades while reductions in numbers and high grade constraints have held them back.

However, more is required. There are other opportunities to help create and maintain a qualified, motivated, and professional work force. Many of the recommended actions outlined here are already started and only need further support and emphasis. The laboratories need to be encouraged and the procedures need to be made easier for the labs to exercise many of these opportunities.

Recommended actions include:

4.1.1 Expand NWC/NOSC Demonstration

- The NWC/NOSC personnel demonstration should be extended to other centers. Under new guidelines, both NWC and NOSC have created excellent personnel programs which reduce the paperwork of administration and greatly emphasize performance as a basis of promotion, competition, and priority under reduction-in-force procedures. These programs are well thought out and working well.

Other laboratories should be directed to submit proposals within the guidelines which governed the NWC/NOSC demonstration and are tailored to the particular geographic, service and skill needs of each laboratory.

4.1.2 Resurrect PL-313-Like Positions

- Resurrect a modest number of PL-313-like positions. During the 60's and 70's the PL-313 position was a powerful tool for quickly and efficiently acquiring the services of specially qualified scientific and engineering skills on behalf of the government. Yet, it was not a very large population. Although a flexible salary level was one of the leverages available under PL-313, the flexibility most important to resurrect is the ability to designate the skill and the person needed and acquire his/her services rapidly. This flexibility is still needed, is not available through the SES process, and should be created.

4.1.3 Reduce Administrative Impact of Civil Service Reform Act

- Reduce some of the administrative burden and excessively bureaucratic procedures introduced by the implementation of the Civil Service Reform Act of 1978. While the motivation for this act was correctly aimed at efficiency and professional performance, and many of its features are

worthwhile, it also produced some glaring new unproductive burdens which should be corrected. For example;

- Senior Executive Service positions are now routinely left open from 12-24 months because of the extensive and lengthy process of filling an open position. Along with the many other difficulties of laboratory leadership, delays of this magnitude are truly damaging. The harsh effects are amplified even more during these times when inequitable pay is causing alarming departures of competent leaders.

- Fix the merit pay system! During visits to the laboratories, no other subject gave rise to such intense and emotional criticism as the Merit Pay System. The laboratory management and the work force felt doubly cheated by the 1981 merit pay exercise. They all dedicated an unreasonable investment of the time and talent of their organizations to fulfill the excessive paperwork burden of its administration (one organization estimated that it cost $5 of effort for every dollar awarded). Then, at the last minute, the government reversed itself and made no distinction in pay on the results. This demonstrated a gross insensitivity by wasting a lot of effort and hypocritically disavowed the underlying objective of the program.

4.1.4 Work on a Differential Pay System

A differential pay system for selected scientific and engineering personnel is needed. The concept of comparable compensation is essential for the health of the government in general, and in the case of selected scientific and engineering skills (at this in history,) it is crucial. Our laboratories, which we agree are essential and must be competent to perform their function, cannot compete with industry in some important aspects under present practices. Most importantly, they cannot compete for B.S. graduates in engineering, computer science, and some specific scientific fields. The salary structures of industry and government may differ by a minimum of $4,000 and routinely as much as $10,000 per year at these low-experience levels. Although some differentiation is already made for engineers through higher entry-level grades, it is totally inadequate and some form of special compensation must be developed.

The second crucial area of competition is at the senior technical manager level. Most of these laboratories and centers involve guiding several hundred to several thousand personnel and several hundred millions to billions of dollars of effort. To expect that the government can acquire and retain the level of professional technical management capability necessary to guide these efforts without special compensation is unrealistic. At least a few positions in each laboratory, R/D center, or major technical activity should be designated for special salary provisions. This would not be expensive (for example 300 positions with an average of $10,000 per year differential would total 3 million/year). It would demonstrate that the government

valued what it was asking these centers to accomplish and the advantages would be amplified manyfold by improved motivation and morale of the 60,000 to 100,000 person work force.

4.1.5 Laboratory and Technical Directors Should Have Tenure

Laboratory Directors and Technical Directors should have substantial tenure positions. It would be desirable that they stay at least 3 years. Corporate memory is a problem for the laboratories and is one of the most criticized aspects of laboratory management by industry.

4.1.6 Expand Student Support Programs

There are also several important actions involving improved educational opportunities which sould be undertaken to help recruiting and retention, improve the competence of the work force, and foster a quality professional environment. No one action is critical but the collective emphasis on the recruiting, retention and improvement of quality personnel is crucial:

- Student utilization programs should be expanded. Co-op programs have proved to be excellent for recruiting high quality young engineers. These programs should be expanded. Where possible, hiring graduate students on a part-time basis should also be increased.

- The Services should increase their use of the ROTC program to acquire scientific and engineering officers.

- Post baccalaureate graduate fellowships for defense science and engineering employees should be expanded, again with a suitable post education commitment.

- There are a few areas of specialization in which the DoD needs call for targeted post-graduate education with the post education work commitment in industry. The Air Force and Army already have such programs in cooperation with industry for thermionic tubes, aero-propulsion vertical lift technology, and other areas. This is a useful approach and expansion should be encouraged.

- A new initiative recommended is that the Services and Defense Agencies should also establish an auxiliary "Defense Engineering Training Program" patterned after the ROTC program. The last two years of college should be supported with a two-year post-education commitment in a civilian defense engineering job. Summer employment opportunities should also be included in this program.

4.1.7 Provide Consistent DoD Policy

Finally, nothing will do so much for the work force and its management as responsible OSD and Service management. If the lab directors and work force had confidence that senior DoD leadership had a clear direction and objectives and that this leadership were prepared to stand firmly for

programs and actions which placed highest values on the primary purpose of creating a Defense capability, it would do wonders.

4.2 STREAMLINE PROCUREMENT PRACTICES

The present practices by which laboratories and R/D centers presently procure material, computers, and services cannot be rationalized. They create massive, unproductive efforts. They cause unnecessary and extensive delays which produce deficiencies in capability, which are usually not recognized or quantified by those enforcing the procurement practices. They violate the good sense of all participants. They cause extensive waste in the industrial sector. No one will defend them as they are.

These judgements are true for the whole acquisition process of the DoD (which is generally better than the rest of the federal government) and thus the laboratories cannot be expected to be extricated completely. However, there are some steps which would substantially reduce the burdens and delays on a large group of small R/D procurements, which constitute a very large percentage of the actions undertaken by the laboratories.

4.2.1 Improve Procedures for Small Contracts (Less Than 500K)

This review was not extensive enough to do a complete job of defining all of the steps needed to improve the procurement process. It is a vast labyrinth of laws and regulations which are intertwined with a language which tends

to keep all but lawyers and contract administration specialists intimidated. However, there are some initiatives which can be reasonably identified.

- The "Determination and Findings" threshold should be raised. Congress has now authorized this to be raised from 100K to 5 million. The Services should assure that the majority of this flexibility is delegated down to the laboratory and R/D center director.

- Special fast-track contracting procedures should be streamlined further for R/D procurements under 500K. Congress has already assisted in this by raising the level above which pre-contract certification is required to 500K.

4.2.2 Relax Technolgy Base Obligation Constraints

Obligation and expenditure constraints should be relaxed for technology-based efforts. The pressures to assure a complete expenditure profile has placed extraordinary constraints on the contracting processes of the laboratories. While this pressure may have a rational basis over the whole investment account, it is inappropriate for the relatively small and numerous contracts of the technology base effort.

4.2.3 Select Study Group to Review Small Procurements

These recommendations, even if completely implemented, are not intended to be complete and they are not

enough. The constraints of the contracting process have gotten out of control and it is recommended that a special team of contract administration specialists be identified to specifically address what can be done to improve the situation for small R/D contracts.

4.3 MODESTLY INCREASE THE RATE OF MODERNIZATION OF FACILITIES AND EQUIPMENT

The laboratories appear to be somewhat more deficient in modernization than the rest of the defense establishment, and less well represented in the resource allocation process. While the life or death of the lab system does not ride on this issue, the labs should be allocated a larger share of the available money for facilities and equipment.

4.3.1 Support LMTF Recommendation on Facilities

Many of the facilities are substandard, inadequate, obsolete, or energy inefficient, and they need to be updated. Also, advancing technology in new programs will require appropriate facilities and new facilities need to be provided to the laboratory community. The Laboratory Management Task Force under USDRE recommended that significant monetary investment in R&D facilities for each Service should be insured over the next 10 years. They sought to have the DoD establish a laboratory facilities modernization policy such that replacement could take place in a timely manner and could be tailored to the characteristics of the laboratory systems in each Service. About $70 million each year for each service over the next 10 years would be required. This recommendation is supported.

4.3.2 Support LMTF Recommendation on Equipment

The general purpose equipment posture of the laboratories is similar. The Laboratory Management Task Force recommended that the DoD modify existing regulations (in this particular case, DoD Directive 7410.4) to permit depreciation charges at appropriate laboratories. Also, they suggest that DoD establish a laboratory equipment modernization policy to insure that general purpose equipment is replaced or acquired in a timely manner. To accomplish this, the Laboratory Management Task Force suggested that each Service have an equipment modernization program of at least $25 million to $30 million each year for the next 10 years. This recommendation is also supported. These facility and equipment modernization programs are necessary if the DoD Laboratory system is to remain competitive in high technology area.

4.4 IMPROVE THE DoD/UNIVERSITY RELATIONSHIPS

A series of actions are recommended to support the goal of improving the DoD University connection;

4.4.1 Support DSB Recommendations to Increase University Support by Defense with Associated Equipment Modernization

This recommendation has been put in place by putting $30 M into the FY83 budget ($10 M per service for the next 5 years for a total of $150 M). This should be dealt with by the Services under the cognizance of DoD to insure that the university equipment is well utilized and that the

program does not become a source of funds for things like oscilloscopes and equipment that could well be purchased by the university. These should be items that are of high interest which provide quality facilities for universities to do DoD research. This equipment needs to be funded within the university community, in part because in years of declining budgets within DoD, the DoD support for university facilities was lacking. This was true in the laboratories as well and is discussed in Section 4.3.

4.4.2 Support DSB Recommendation to Establish New S&E Fellowships

The DSB recommended the establishment of new scientific and engineering fellowships in the universities. The DSB recommendation included a $15,000 stipend to the student during the time that he is involved in the university education process. The fellowships will help get post-graduate education on its feet and will help the universities develop a faculty and develop areas of expertise such that it will be possible for the university community to be preeminent in science.

4.4.3 Continue the Dialogue Regarding the Security of Intellectual Property

The issue of secrecy regarding scientific and technical information relevant to the creation of military capability is a potentially divisive issue between the DoD and the academic sector. The problem is a broad one and extends well beyond the laboratory interface with universities. It is of critical importance to this interface,

however, and it is imperative that a dialogue continue between all parties in pursuit of a rational solution.

4.4.4 Expand Student Utilization Programs

The student utilization programs should be expanded. Co-op students are good sources of new people for the laboratory community. Once people are involved in the laboratory in the summer co-op programs, they generally will at least consider the laboratories favorably when looking for a job after graduation. Along the same lines, graduate student hiring should expand. In this case, the university graduate students can work part time in the DoD laboratory, obviously if it is close to the university.

Another area of student utilization programs is research assistanceships. The Air Force and the Army both offer research assistanceships which are essentially fellowships whereby the student is given a stipend but he does not have to spend any time in the Service or in the Civil Service. These assistanceships are in areas of critical need for the Service. The Army has programs in helicopter aerodynamics and helicopter design, the Air Force has programs in thermionic engineering, composites and propulsion. These programs are designed to build up the technical expertise of the country so that the DoD will have access to such expertise and that there will be people who can be called on as consultants from private industry to work on difficult or time critical problems.

4.4.5 Establish a Two Year Undergraduate Program for Civilian Employment Patterned after the ROTC

In addition to the DSB suggested increase in the ROTC programs, a two-year undergraduate program should be established for the last two years of college, providing an engineering degree while requiring DoD employment for two years afterwards. This would essentially provide the same benefits as the ROTC program, except it would appeal to those who are not sure they want to serve two years in the military, but would like to serve two years in a Defense position. This may provide a different kind of incentive to university people in their junior and senior year which might also entice them to stay on with a DoD technical activity. This seems like a particularly good idea at the lower experience levels where the Services need to recruit quality people, but have problems in that industry is offering much higher salaries than the DoD can offer.

4.4.6 Increase DoD and University Emphasis on Industrial Education Related to Logistics and Manufacturing

Some of the DoD deficiencies in our logistics and manufacturing techniques are derived from the more general national problem of lack of emphasis and shortage of skilled personnel in this area. The DoD and universities should work together to enhance the prestige of these critical professions, enhance the curricula in the universities, and increase the number of students being trained.

4.4.7 Establish Defense Centers of Excellence with Universities in New Technology Areas

There should be Defense centers established with universities in new technology areas. These new technology

areas would include simulation, micro-electronics, artificial intelligence and software research and automation. These new technology areas are ripe for starting new curricula in universities. They would be multidiscipline in nature and cross departmental. However, there must be a mutual need to establish a center of expertise with university help and university participation. This idea seemed to work well where the Army's Corps of Engineers' Construction Engineering Research Laboratory is co-located with the University of Illinois and the Cold Regions Research and Engineering Laboratory is at Dartmouth College. Both of these have a benefit for the university and the Service. Laboratory people co-located can use the same facilities and provide an interchange between the day-to-day practical problems of the Defense Department with the perhaps more theoretical aspects of the university and the faculty research programs. Expanding into new areas provides a good method for increasing the involvement of universities in DoD research and development, but it does it in a way that involves the faculty, the students and the DoD researchers as a team.

4.5 ESTABLISH EXTERNAL ADVISORY GROUPS FOR EACH LABORATORY

The Services and Service labs should be encouraged to establish external advisory groups drawn from industry, universities, and operational command representatives. Although the interaction with such groups brings with it a substantial investment of time and energy and there can be a conflict of interest issues. They can:

- Bring external competence to the problems of the laboratories;

- Be a source of new ideas and perspective;
- Provide a valuable component of corporate memory for a laboratory, and;
- Assist in providing visibility to lab activities for industry and academia.

The value of these contributions can be great and well worth the investment. It would be natural for these to be formed under each service science advisory board and to participate in the effectiveness review recommended elsewhere in this report.

4.6 ESTABLISH AN EFFECTIVENESS REVIEW PROCESS FOR THE LABORATORIES

A number of benefits would result from the creation of process for external expert review of the laboratories and R/D Centers every 3-5 years.

The basic objectives of this initiative are:

- To provide a routine and credible means of assessing the health of each laboratory and research, development and acquisition process in which that laboratory is imbedded;
- To provide an additional mechanism for visibility of the DoD R/D activities by industry, the universities, and operational military representatives, and;

- To provide a channel for the display of in-house direction and work to nationally recognized experts.

The USDRE should task the Defense Science Board to establish a permanent panel to develop the criteria to be applied, define the process of review, and monitor the implementation. The Military Departmental Scientific Advisory bodies should be the primary means used to review Service laboratories and DSB should take the lead for any other laboratory or technical activities to be covered by this process. In order to prevent unnecessary duplication, the individual advisory bodies for each laboratory, recommended elsewhere in this report, should be employed.

4.7 IMPROVE INDUSTRIAL VISIBILITY OF LABORATORY ACTIVITIES

One of the major complaints of industry is that the laboratories too often compete with industries in areas where industry can perform. They further feel that this competition comes from a privileged position in terms of decisive influence and access to information. They note that industry provides detailed reviews of their independent research and development; whereas, the labatories rarely provide such a view to industry.

In many aspects there is no way to avoid the special decision role which the labs must play and their privileged access to government intentions and information is necessary. Nevertheless, these complaints have a major element of truth behind them. Even though they are often

57-279 O - 87 - 41

extrapolations of isolated experiences, actions can and should be taken to reduce the sometimes unnecessarily adversarial nature of lab-industry interactions.

- A principle initiative should be an annual publication by each DoD laboratory describing its in-house R/D activities as a counterpart to industry's R&D technical plans. There are limitations to this symmetry, of course, since the government must control access to sensitive information. Thus, the laboratory publications can only go as far as practical at the unclassified level.

- Industry participation in laboratory advisory groups and evaluation reviews will also provide some improved accountability of government interactions and activities.

- Industry participation in the development of the operational concept projection recommended elsewhere in this report will be helpful as well.

4.8 DEVELOP A FORMAL PROCESS FOR AN OPERATIONAL CONCEPT PROJECTION AND APPLICATION

In order to sensibly evaluate and prioritize DoD efforts to create and apply technology to the problems of national defense, it follows that we must have some notion of the nature of the military operations to which these applications might be applied. The Defense Science Board Summer

Study panel on technology base found this logic appropriate in the methodology they used to identify technologies with potential for "order-of-magnitude" changes. Under the term "Scenario projection," they developed a brief description of some of the most relevant features of how military operations might be conducted in the 1990's in order to assist in the prioritization of new technology opportunities. The Department of Defense should now undertake to develop and maintain a more complete and rigorous document which would project technology opportunities and likely future military operational concepts in a form which would be useful in guiding technology development and application.

The existing procedures for developing and stating required operational capabilities are both essential and useful, but also inadequate to project the nature of military operations ten and twenty years into the future in language useful for making technology management decisions. Yet, that is the time of operational maturity for the weapons and systems which will be generated through application of technology choices of today. The operating commands are not properly staffed to assess and project the combination of technology opportunities and operational procedures which together are likely to form the operational concepts of the future. The laboratories are not charged with this responsibility and find it difficult to participate in the operational requirements process. Present Service staffs attempt through various techniques to make this projection and do so with some success. However, where new concepts might cross Service (or Allied) boundaries, or cause a substantial change in roles, missions, or doctrine, these techniques are severely limited and have not proven to be adequate.

There also exists a widespread conviction that the overall DoD capability to plan, project, and strategize with consistency is not adequate. This, of course, makes it more difficult for subordinate functions such as technology managers to do consistent planning within a larger effort. This initiative is not recommended as a means of solving the broad Defense planning and projection problem. Rather, within the vagaries that will always exist to some extent in our top-level planning, this projection of likely operational concepts is intended to assist in forcing technology choices to be focused on a value system of operational utility.

The Secretary of Defense should task the Defense Science Board to supervise the preparation of this projection and to update it every two years. The DSB is an appropriate body because it is the premier advisory body to the Secretary of Defense and has within its membership nationally recognized leaders in scientific, industrial, and military thinking and can mix that membership with active government, military and civilian leaders. This mixture of separate professions and competencies has been, over the years, a dominant force in influencing (in many ways) how our defense establishment is structured. It is important to capture their judgment in an orderly manner for the purpose of building a consensus strategy to create and apply new technology.

Finally, a small, permanent supporting staff should be organized as the secetariat for this effort. It should be contained within the new Center for Strategic Concepts Development now being organized at the National Defense University to increase their emphasis on the military operational arts. Assignment of this responsibility should provide some useful synergism and complementary emphasis.

The "Operational Concepts Projection for Technology Management" should be submitted to the Secretary of Defense by the DSB after it has been reviewed and commented on by the Joint Chiefs of Staff, Unified and Specified Commands, the Military Services, appropriate Defense Agencies, and OSD Staff elements.

4.9 EXPAND LABORATORY RELATIONSHIPS WITH OPERATIONAL FORCES

One of the most common criticisms of the laboratories is the apparent lack of coupling between what the laboratories are doing and sponsoring and the needs of operational commands. This judgement is reflected in many forms:

- Those who have the opportunity to observe our forces often note that these forces are not modern in many ways and that very reasonable application of newer technology could have great leverage. They conclude, therefore, that the transition process is not working well.

- There has been an increasing awareness that some of the sources of major weakness in our operational forces is lack of reliability, maintainability, and supportability of equipments being provided. Nevertheless, the primary drive from the laboratories and the program managers often seems to be the application of new science and new technology to improved technical performance without emphasis on manufacturing and logistics.

- Many of the more contemporary advances in military force capability involve the application of technology and highly technical systems skills to the force management problem(C^3), to the application of signals in military operations (EW), and to the application of intelligence and sensor products to support platform and unit maneuver and weapons control.

Most laboratories are organized around an engineering function, a military platform, or a producible commodity and are not as capable of dealing with the whole and the connecting networks involved in grouping these all together with men and procedures into a command organization to create a force.

- There are great opportunities to apply available technology and competent technical judgment to the systems and forces now in the field with great leverage. However, we are organized primarily to bring new technology into the field through the developments of new systems, not the application of new technology to existing systems. Product improvement of fielded forces could be enhanced significantly if we recognized that product improvement and logistics support are truly sophisticated technical functions, worthy of our finest and most innovative people. Both organizationally, and culturally, we need to recognize and foster these useful applications of technology in support of military forces for there are great

opportunities available. These opportunities can often be less expensive, more quickly implemented, and more rapidly integrated into the operational, maintenance, training, and support environment of the forces.

The objectives of this initiative are:

- To improve the laboratory awareness and understanding of the operational concepts which their scientific and engineering efforts are supporting;

- To illuminate the reliability, maintainability and supportability issues for both the laboratories and the commands they ultimately support;

- Provide an improved channel for laboratory and command cooperation in fielded product improvement, and;

- Provide an improved mechanism for the evolutionary application of technology to improve command C^3, EW, and intelligence application.

To accomplish this, the unified, specified, and subordinate component commands should be given modestly sized technical staffs, some development funds, and the responsibility for the definition of and, on a limited scale, the acquisition of evolutionary force improvement through field system modifications and improved coupling or netting of assets.

The command technical staffs should be formed from the personnel from the laboratories under personnel administration and career management of the laboratories but operating as an integral part of the commander's staff. The Services should take the responsibility for providing these staffs and the funds for the specified Service component commands perhaps through a designated lead laboratory. USDRE should arrange for Unified Command needs through the Service and Defense Agency laboratories and technical centers.

4.10 STRENGTHEN THE SERVICES LOGISTICS R&D PROGRAMS

One of the most pervasive problems of fielding a modern force with the new technologies available is the logistics tail associated with the new systems that are developed and produced. The underlying issues have a sophisticated technical content but we have inadequate mechanisms to bring to bear the best technical minds to this subject. The logistics and supply organizations of the services are trying to develop better capabilities and techniques but it is slow, in part because of the tendency to view logistics as a less sophisticated and less glamorous career than the design of new systems. Historically the laboratories have been aimed primarily at the application of new technology in the development of new systems with improved technical parameters. Thus, the focus on logistics has been secondary at best.

This review did not reveal any new, well ordered set of actions by OSD to resolve the situation. It would be inappropriate, however, to take no action towards improvement. It is also clear that any decisive action must be taken by the Services because the logistics function is

completely embedded in the Services "organize, equip and train" role.

It might fairly be argued that the issue is not primarily a "laboratory issue" except that the laboratories, as presently constituted, do play an important role in the early phases of development of a new system. It has also been argued that new logistics laboratories are needed by each service. This review did not develop enough data or testimony to recommend either for or against this latter suggestion.

It is recommended, however, that each military department be tasked to establish a formal "Logistics R&D Program" with appropriate program element and program management structure and report back to the Secretary of Defense their plans for the conduct of such a program. These programs should at a minimum cover diagnostic techniques, weapons system logistics analysis, automated documentation, advanced maintenance concepts, and logistics management and control systems.

4.11 EXPAND TECHNOLOGY DEMONSTRATIONS

The tremendous development of new technology in the past 30 years has brought rapid increases in new capabilities for weapon systems, but often accompanied by increases in sophistication and complexity. This is particularly true in electronics, not only in the radar and radio world, but also pervading every major weapon system in the form of chips and sensors. These increases in capability, sophistication and complexity require new ways of doing business for the DoD laboratories, for the industrial community and for the Armed Forces.

Too many problems appear after the engineering development process has been initiated. Problems of technology, reliability, producibility, and useability begin to show up and result in dollar and schedule overruns. Often major changes can be made in a relatively simple manner and at low cost when caught early, sometimes even small changes are difficult and expensive to achieve when made at the end of the cycle.

The transition to full scale engineering devlopment is not only a critical point in the devlopment cycle, but unfortunately, is where disconnects usually occur. It is often at this juncture, that the DoD lab transfers a great deal of in-house activity to industry. It is also at this point that the need to develop a method to best fit the needs and concepts of the operational military plans is most critical.

The demonstration and evaluation of critical technologies in an operationally relevant form can often be a useful means of helping to assess the appropriate mode and the military value of a technological application. However, these demonstrations can be expensive and are often not undertaken by the military Services in favor of other needed and less risky applications of resources.

Senior DoD management has historically disagreed with this priority judgment by the Services and has found it convenient to use DARPA as a primary vehicle for such critical technology demonstrations. While this has produced some salutory results, it has also produced some antagonisms between some elements of the Services and DARPA which have

worked against the end objective of fair evaluation and ultimate transition of the technology in question into operational capabilities.

The objectives of this initiative are:

- To provide a mechanism for evaluating and prioritizing critical technology demonstration efforts;

- To increase the level of Service critical technology programs, and;

- To reduce the sources of conflict between DARPA and the Services.

It is recommended that $300-400 million be set aside by USDRE to be used to support the most worthy proposals for critical technology demonstrations submitted by the Services and Defense Agencies, including DARPA. Operational and Training Commands should also be encouraged to develop proposals for in-the-field demonstrations particularly in support of the C^3 and Electronic Warfare functions.

4.12 ESTABLISH A DEFENSE CENTER FOR SIMULATION RESEARCH AND DEVELOPMENT

Advances in modern computer and display techniques make it possible to develop and perform simulations of military systems and operations with a power and realism heretofore unachievable. This is true at the weapon level; platforms and small units; for large unit exercise and tactics

development; and for large campaign representation and doctrinal development.

The need to simulate these various levels of military activity has also increased because;

- The price of energy and the cost of weapons operations have escalated such that sustained live practice and training is often prohibitively expensive. As a consequence, we have a large percentage of our uniformed service men unpracticed in the use of weapons we paid dearly to acquire and we depend on for our security.

- We need ways to develop military operational experience without engaging in conflict. Too much of our practiced doctrine and concepts, particularly at the theater and tactical level, are dominated by lessons learned in WWII, Korea, Southeast Asia, and Mideast conflicts. All agree that none of these are representative of most future conflicts involving U.S. forces. Strategic force planners long ago learned to depend on analysis, exercise and simulation to define the rules of combat in regimes never experienced by man. Theater and tactical level planners must do the same and an increased capability to simulate will make this possible.

The art and practice of simulation has a strong part in present military sevice practice and is an expanding area of interest and investment. It is, properly, distributed to many different developmental and operational activities in order to tailor the application of simulation

techniques to the needs of the particular training or operational commands. This has, however, fractionated the effort with the resultant lack of focus on generic research, common development, maintaining a repository of information about the state-of-the-art, and, most importantly, the development of a community of skilled professionals in the simulation discipline.

This recommendation proposes the establishment of a center of excellence for the application of simulation techniques to the military arts. The objective is the creation of an institution which would insure the continued development and improvement of our skills, capability and practice of military system and force simulations. There are a variety of organizational options to achieve this objective and this review was not sufficient to advocate any particular course of action. However, some elements of an adequate approach include;

- Close association with one or more universities. The context of a simulation program should be very compatible with the aims and capabilities of several universities. This association should be of value to all parties.

- The creation of a private sector organization (such as or similar to the Applied Physics Laboratory of Johns Hopkins University) as a core work force for the development of long-term, professional quality in simulation techniques.

- The constraint of the center to research, equipment and technique development and acquisition,

and technical support to operational and training activities. This role as an organization designed to develop techniques and promote professional technical expertise should dominate rather than act as a bureaucratic coordination or management role function.

A major issue with this recommendation is whether any new organization should be formed around or even include the existing training equipment activities of the Services. They certainly form a large existing body of competence, albeit limited in scope, from which to grow such an organization with its expanded role. Conversely, one can be concerned that development of this broader role might become subordinate to the on-going needs for fielding equipment already defined. In spite of this latter risk, proceeding from the base of these training equipment establishments is recommended.

An ad hoc group should be formed to develop a more detailed implementation plan to form a Defense Center for Simulation Research and Development located with the Naval Training Equipment Center and the Army Program Manager for Training Devices. The Air Force should also establish a larger presence at Orlando as a part of this action. Some additional resources may be required but for the most part the new thrust should be created through private sector organization preferably with a university association. An opportunity for a mutually attractive association may exist at Orlando with the University of Central Florida.

Executive responsibility for the center, which should be defense - wide in scope, should be given to the

Commander NTEC who would respond for these new responsibilities to policies and with resources provided through an executive council of service and agency representatives, chaired by a senior OSD official.

4.13 ESTABLISH A NEW CENTER FOR MICRO-ELECTRONICS AND COMPUTER SCIENCE

The remarkable advances in micro-electronics devices, new sensors, large computers and display systems have created profound new technology opportunities in defense systems. The proliferation of breakthroughs in these areas apply to almost all aspects of military systems acquisition, integration, and operations. It would be fair to say that the maintenance of an effective U.S. military force in the future depends, in large part, on the competence we develop and the judgment we use in the application of these technologies to our Defense and National Security Systems. However, the competence and dynamism of the existing defense institutions and their relationships with industry are clearly inadequate to address the problem with the urgency required. The need to develop this competence and the institutional mechanisms to translate these technologies into operational systems and practice is so overriding that additional extraordinary management initiatives are appropriate.

There is an awareness of the pervasive impact of these phenomena throughout the whole defense community including the existing laboratories and R&D centers. It is not for lack of conviction that the Defense technical community is inadequate in this area. However;

- The government personnel system cannot compete with the private sector for the new skills needed;

- The governmental process for capitalizing new industrial capabilities through its military construction and general purpose equipment programs is far too slow to respond to this rapidly changing area;

- Many of the high-leverage applications address the integration of separate systems to form operational forces. Our collective ability to manage the injection of new technologies into these integration functions such as command and control, electronic warfare, and application of sensor products is extremely difficult, and;

- This proliferation of breakthroughs in the new micro-electronic phenomenology and devices has not been accompanied by parallel breakthroughs in our ability to develop, test, and maintain the necessary software. The need for automated and fault-tolerant design techniques and efficient testing of micro-electrical systems is recognized by both the government and the private sector, but both feel very much behind in their ability to support the software aspects of the problem.

The objectives of forming a new center for micro-electronics and computer science are:

- To create an institution capable of acquiring and retaining the requisite personnel and facilities needed to create and sponsor the creation of new technologies and techniques for Defense needs in the areas of;

  - very high speed and density devices,
  - artificial/machine intelligence,
  - signal processing,
  - software development and automated design and test,
  - new generation Defense oriented computation systems,
  - and to assist in the application of these technologies and techniques into operational systems and practices.

There are a great variety of organizational alternatives by which these objectives might be met. During the course of this review several were briefly evaluated including:

- Expand the role of a single existing service laboratory under a Service executive agent arrangement (an example would be the Army's Electronic Technology and Devices Laboratory at Fort Monmouth, New Jersey);

- Expand the role of one center in each Service;

- Expand the role of one or more non-government center such as SANDIA, APL, or Lincoln Labs, and;

- Create a new institution with a variety of optional forms;

  - primarily government manning capitalization,
  - primarily non-government,
  - primarily university: one or many,
  - various mixtures of government, non-government, and university.

A new institution formed primarily of non-government personnel is recommended. This will provide the best environment for recruiting and retaining the personnel skills necessary to create a center of excellence in these fiercely competitive areas. The creation of a new, defense-wide center in this field along with existing Service and agency laboratories will require careful delineation of responsibilities. However, this should be quite practicable. The area is worthy of increased effort and the Services need their own institutions to aggressively translate these new technologies into the forces.

This study could not give the time and talent necessary to define a specific organizational approach for this new center. It is recommended that the USDRE should establish a separate ad hoc group with membership especially competent in this field to develop the detailed plans, directives, and perhaps legislation needed to proceed.

4.14 FORM AN ELECTRONIC WARFARE TECHNIQUES DEVELOPMENT CENTER

Advances in technologies such as propulsion, materials, micro-electronics, communications, and information

handling have created new weapons and supporting systems which have profoundly affected the nature of modern military operations. Munitions are more lethal and delivery systems can deliver them farther, faster and more accurately. This requires, and technology permits, more precise target acquisition at greater distances, and the control of both weapons and sensors at a distance. All of these trends have caused a fundamental dependence of modern military weapons and forces on electronic and signaling techniques.

Under the functions labeled "Electronic Warfare," "Signal Warfare," "C^3 Countermeasures," "Radio Electronic Combat" and/or "Electronic Combat," modern military establishments are developing capabilities to maneuver in this new regime of military operations. For the U.S. and its allies, the processes for specifying and acquiring the hardware needed is most advanced, but their ability to integrate this hardware into effective operational capabilities is not as well developed. The Soviet Union, however, has placed much greater emphasis on the operational concepts and institutional structures necessary to achieve this integration under their "radio electronic combat" functions and organizations.

The objective of this initiative is to strengthen the DoD capability to develop and apply new electronic warfare techniques. To do so it is proposed that a strong systems engineering capability be added to the Joint Electronic Warfare Center in San Antonio to complement existing science laboratory efforts. At present, the JEWC consists of approximately 140 personnel who are primarily non-technical with strong intelligence or operational backgrounds. In order to develop the new techniques appropriate for modern forces in future operations, it is necessary to include both

the potential of advanced technology as well as operational concepts and doctrine.

By making a substantial addition to the ability of the JEWC to address both the technology and operational aspects of electronic warfare, it can markedly improve its ability to develop such products as:

- Joint EW procedures and techniques,
- Analysis evaluations of alternative EW methods and techniques,
- EW simulation capabilities and results,
- EW test and evaluation proposals and evaluations,
- Technical support to operational and training commands, training, and exercises.
- EW data bases.
- A library or repository for EW related information and techniques.

This technical strengthening of the JEWC is not intended to, nor should it, compete with the Service efforts which are primarily hardware oriented. The JEWC should focus on joint techniques, new combined technology-operational techniques, and test and evaluation support. It will require the JEWC to be charged with an on-going responsibility for these functions and not merely respond to the tasking of others as is now generally the case.

4.15 ESTABLISH A FORMAL COMMAND AND CONTROL RESEARCH PROGRAM AND CENTER

Many of the technology and operational trends which support aggressive actions to strengthen our Electronic Warfare capability also support the need for increasing our

application of technical skills to the function of command and control. The objective of this initiative is to accelerate that process at the research end of the creative process through the development of analytic concepts and rigor in the command and control field. It is completely consistent with the DSB report of 1978 on C^3 acquisition.

A modest Command and Control Research Center should be established at the Naval Postgraduate School as a companion organization to the NPS C^3 postgraduate activity. This center should perform and sponsor C^2 research which should include aspects of:

- Control theory
- Game theory
- Quality theory
- Utility theory
- C^2 modeling and simulation.

The center should not be capital intensive but rather should depend on the C^3 postgraduate facility, service test bed facilities such as exist at NOSC, and live field environments for their research facility needs.

In addition to the C^3 research aspects treated above, there is also a need for additional emphasis on the application of technical judgment to the development and acquisition of new command and control capabilities. However, these processes are fundamentally evolutionary in nature and this evolution which must be controlled from a position embedded in the command function. Therefore, strengthening these aspects is best accomplished by establishing a strong configuration management function within the

operational commands. The initiative treated elsewhere in this report to strengthen our command relationships could thus be an important assist in the command and control area.

THE UNDER SECRETARY OF DEFENSE

WASHINGTON D.C. 20301

RESEARCH AND ENGINEERING

3 SEP 1981

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
DIRECTORS OF DEFENSE AGENCIES

SUBJECT: Review of DOD Laboratories - ACTION MEMORANDUM

In several recent examinations of the Defense research and advanced development process, the government laboratories which guide that activity, and the associated scientific and engineering work force, there is recurring evidence that the long-term health of the laboratory structure is in jeopardy. I am therefore initiating an intensive, high-level review of DOD laboratories to be undertaken under the direction of Dr. Robert Cooper. Dr. Cooper has asked that this effort be headed by Dr. Robert Hermann, 695-0578, who will be supported by a small ad hoc task force staff and a senior outside advisory group. The date for completion will be March 1, 1982.

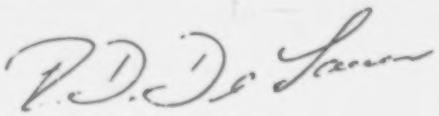
The objective of this effort is to identify those high leverage actions which we need to take to insure the long-term health of a sound DOD laboratory structure. At minimum, the product of this review will address:

- how the laboratories and their products are used,
- personnel practices,
- procurement practices,
- the laboratory management structure and process.

Your support and participation is requested in these areas.

. The Services should identify a qualified officer or civilian to serve as a member of the task force staff from September 1981 through March 1982.

. All should provide a point of contact to work with Dr. Hermann to facilitate laboratory visits, data gathering, and product review and coordination.



cc: Dr. George A. Keyworth

STUDY GROUP PARTICIPANTS

The following individuals were members of the study group:

Study Team Leader:

Dr. Robert J. Hermann	- Special Assistant for Intelligence to the Under Secretary of Defense for Research and Engineering

Army:

Mr. James A. Bender	- Director, Tech-Planning and Management Directorate, DARCOM
Mr. James E. Spates	- Ass't Dir. for Laboratory Activities Directorate of Army Research
Dr. Ravinder K. Jain	- Chief, Environmental Div. Construction Engineering Research Lab Champaign, Illinois

Navy:

Dr. Theodore A. Jacobs	- Dep. for Tech. Base, Office of Ass't Sec. of the Navy for Research

Air Force:

Col Richard H. Hartke USAF	- Vice Commander, Air Force Office of Scientific Research

DARPA:

Mr. David T. Petter	- Executive Ass't to the Director, Defense Advanced Research Projects Agency (DARPA)

In addition, the following individuals were of great assistance to the study effort.

Dr. Bernard A. Kulp	- Scientific Advisor to the Director of Laboratories Air Force Systems Command
Captain David F. Parrish USN	- Ass't Deputy Chief of Naval Material for Laboratory Management

INDUSTRY ADVISORY GROUP FOR REVIEW OF DoD LABORATORIES

Mr. Richard Alberts
Research Triangle Institute
Rt. 2, Box 477
Chapel Hill, NC 27514

Dr. Arden Bement
TRW, Inc.
2355 Euclid
Cleveland, OH 44117

Dr. Ivan Bennett, Jr.
New York University Medical Center
550 First Avenue
New York, NY 10016

Dr. Art Chester
Hughes Aircraft Company
P.O. Box 902
Bldg. E51, M.S. A269
Segundo, CA 90245

Dr. Edward Gerry
W. J. Schafer Associates
1901 N. Ft. Myer Drive
Suite 803
Arlington, VA 22209

Dr. William Krebs
Arthur D. Little, Inc.
Acorn Park
Cambridge, MA 02140

Dr. Reuven Leopold
General Electric Co.
1000 Western Avenue
Lynn, MA 01910
Mail Drop 174AB

Dr. Frank Mayadas
IBM
T. J. Watson Research Center
Box 218
Yorktown Heights, NY 10598

Mr. Charles McKinley
Vought Corporation
P.O. Box 225907
Dallas, TX 75265

Dr. Lowell Steele
General Electric Co.
Fairfield, CT 06431

Dr. Harry J. Woll
RCA Electronics Products, Systems and Services
David Sarnoff Center
Princeton, NJ 08540

Chairman
Mr. Donald J. Looft
Magnavox
Electro-Optical Systems
46 Industrial Avenue
Mahwah, NJ 07430

INDUSTRIAL ASSOCIATION'S PARTICIPANTS

The study team asked the following four associates for their respective perceptions on the "DoD Laboratory Problem". In each case the association responded with well thought-out and poignant solutions to the problem. Their earnest participation is greatly appreciated. Much of their input directly impacted upon the study recommendations.

American Defense Preparedness Association

Dr. Elliott Axelband, Hughes ACFT
Mr. Fred Bagby, Battelle, Columbus
Dr. Walter Beam, Sperry
Dr. George Friedman, Northrup
Dr. Hy Lyon, Texas Instruments
Dr. Louis Medin, IBM
Dr. Fred Ordway, ARTECH
Dr. Sidney Ross, RCA
Dr. Leonard Weisberg, Honeywell
Dr. Sam Rothman, George Washington University

National Security Industrial Association

Dr. Max Magner, Dupont
Mr. Frank Lanier, Goodyear Aerospace
Mr. Ed Zaucha, IBM
Mr. John Oblak, United Technology
Capt. Thomas Burley (USN-RET), NSIA
Mr. Douglas Heller, Martin-Marietta

Aerospace Industries Association

Dr. Edward Taylor, TRW
Mr. Sam Rogers, Grumman
Mr. John Tormey, Rockwell
Dr. M. Baron T. George, AVCO
Mr. John Stuntz, Westinghouse
Mr. C. Ronald Lowery, AIA
Mr. Stanley Siegel, AIA

Electronic Industries Association

Mr. Douglas Heller, Martin-Marietta
Mr. Sumner Perlman, GTE Products
Mr. John Chiasson, GE Syracuse
Mr. Arther Flathers, GE Space Center
Mr. William Russell, RCA
Mr. Edward Nucci, EIA

PEOPLE INTERVIEWED

Dr. David E. Mann, former Assistant Secretary of the Navy (Research, Engineering & Systems)

Dr. Alton G. Keel, Assistant Secretary of the Air Force, Research, Development and Logistics)

Mr. Walter Morrow, Director, Lincoln Laboratories, MIT

Dr. Gerald P. Dinneen, Corporate Vice President for Science And Technology, Honeywell, Inc.

Mr. Robert R. Everett, President, The MITRE Corporation

Mr. Alexander J. Tachmindji, Vice President and General Manager Washington C^3 Operations, The MITRE Corporation

Mr. Kent Kresa, Northrop Corporation

Mr. Bert Fowler, The MITRE Corporation

Dr. James Early, Lockheed Aircraft Corporation

General Robert T. Marsh, USAF, Commander Air Force Systems Command

Dr. William J. Perry, Hambrecht and Quist

Dr. Eberhardt Rechtin, President, Aerospace Corporation

Lt General Richard Henry, USAF, Commander Space Division, Air Force Systems Command

Dr. John Eagan, Sanders Associates

Mr. Morton Goulder, Consultant

Mr. James E. Colvard, Deputy Director of Naval Material

Mr. Anthony R. Battista, House Armed Services Committee

Dr. Walter B. LaBerge, Executive Assistant to the President, Lockheed Missiles and Space Company

Mr. Norman R. Augustine, Martin Marietta Aerospace

Dr. Thomas E. Cooper, House Armed Services Committee

Mr. George F. Steeg, Vice President, Plans & Business Development, AIL (Eaton Corporation)

Mr. Lewis R. Franklin, ESL Incorporated

Dr. Jack Kerrebrock, National Aeronautics and Space Administration

Dr. Walter R. Beam, Vice President Research & Development, Sperry Corporation

Dr. Eugene Fubini, Consultant

Dr. Harry I. Davis, Consultant

Major General Frank P. Ragano, American Defense Preparedness Association

Dr. Solomon J. Buchsbaum, Vice President, Bell Laboratories

Major General Emmett Paige, Jr. USA, Electronics Research and Development Command

Major General Brien D. Ward, USAF, Director of Laboratories, Air Force Systems Command

Rear Admiral Joseph S. Sansone, Jr., Deputy Chief for Contracts and Business Management, NAVMAT

Dr. George H. Heilmeier, Texas Instruments

U.S. ARMY LABORATORIES/FACILITIES VISITED

NIGHT VISION AND ELECTROPTICS LAB (NVL)	FT. BELVOIR, VA.
BALLISTICS RESEARCH LAB (BRL)	ABERDEEN, MD.
HUMAN ENGINEERING LAB (HEL)	ABERDEEN, MD.
CHEMICAL SYSTEM LAB (CSL)	EDGEWOOD ARS, MD.
MEDICAL RESEARCH INSTITUTE OF CHEMICAL DEFENSE	EDGEWOOD ARS, MD.
PM TRAINING DEVICES (PM TRADE)	ORLANDO, FL.
ELECTRONIC TECHNOLOGY & DEVICES LAB (ET&DL)	FT. MONMOUTH, N.J.
U.S. ARMY COMBINED ARMS CENTER	FT. LEAVENWORTH, KS.
COMBAT SURVEILLANCE AND TARGET ACQUISITION LAB (CSTL)	FT. MONMOUTH, N.J.
LARGE CALIBER WEAPONS SYSTEMS LAB (LCWS)	PICATINNY ARS, DEL.
FIRE CONTROL AND SMALL CALIBER WEAPONS SYSTEMS LAB	PICATINNY ARS, DEL.
U.S. ARMY MISSILE LAB	HUNTSVILLE, AL.
ELECTRONIC WARFARE LAB (EWL)	FT. MONMOUTH, N.J.
COMMUINICATIONS ELECTRONIC COMMAND (CECOM)	FT. MONMOUTH, N.J.

U.S. AIR FORCE LABORATORIES/FACILITIES VISITED

ROCKET PROPULSION LAB (RPL)	EDWARDS AFB, CA.
ROME AIR DEVELOPMENT CENTER (RADC)	GRIFFITHS AFB, N.Y.
NORTH AMERICAN AIR DEFENSE COMMAND (NORAD)	COLORADO SPRINGS, CO.
WRIGHT AERONAUTICAL LABS	WRIGHT PATTERSON AFB, OH.
MATERIALS LAB	
AVIONICS LAB	
FLIGHT DYNAMICS LAB	
AEROPROPULSION LAB	
AERO-MEDICAL RESEARCH LAB	WRIGHT PATTERSON AFB, OH.
HUMAN RESOURCES LAB DETACHMENT	WRIGHT PATTERSON AFB, OH.

57-279 O - 87 - 42

U.S. NAVY LABORATORIES/FACILITIES VISITED

NAVAL UNDERSEA SYSTEMS COMMAND (NUSC)	NEWPORT, R.I.
NAVAL TRAINING EQUIPMENT CENTER (NTEC)	ORLANDO, FL.
NAVAL OCEAN SYSTEMS CENTER (NOSC)	PT. LOMA, CA.
NAVAL WEAPONS CENTER (NWC)	CHINA LAKE, CA.
NAVAL RESEARCH LAB (NRL)	WASHINGTON, D.C.

THE DEPARTMENT OF DEFENSE

REPORT ON

THE TECHNOLOGY BASE AND SUPPORT OF

UNIVERSITY RESEARCH

for the

COMMITTEES ON ARMED SERVICES
UNITED STATES CONGRESS

1 March 1985

The Department of Defense
Report on
The Technology Base and Support of University Research

	Page
TABLE OF CONTENTS	i
Chapter I: Introduction	1
Chapter II: DOD Support of Universities	6
Chapter III: DOD In-House Laboratories	37
Chapter IV: DOD Industry Interactions	53
Chapter V: Technology Base Activities of Our Allies	72
Chapter VI: Conclusions	81

CHAPTER I

INTRODUCTION

The Senate Committee on Armed Services expressed concern, in a report dated May 31, 1984, "over the lack of growth in the Defense technology base over the past 2 years" and stated their belief that "the technology base programs represent our investment in future defense capabilities." Focusing on Department of Defense (DOD) support for university research, the Committee said that "DOD must do its share to maintain the excellence of our scientific infrastructure through strong support of university research." The Committee requested a report "on DOD activities and plans to support the United States infrastructure for science and engineering education and research." The Committee directed that the report "should address the role of DOD in the education and training of engineers and scientists for technologies used by DOD through (1) the support of university research, including independent research and development, (2) the interaction of defense contractors with the universities, (3) the use of fellowships, internships, and cooperative education, (4) the upgrading of university research instrumentation and facilities, and (5) the maintenance and development of technical skills in DOD laboratories. The report should also address how we, our NATO allies and Japan could work more effectively together in long term research to maintain our scientific and technical lead over

the Soviet Union." This report is submitted in response to that request.

In the long run, a strong United States science and technology (S&T) base is essential for maintaining the nation's military and economic position. The DOD S&T program is a major contributor to this effort to strengthen our national defense. Some relevant achievements accomplished or progress made in the program include:

1. Early development of lasers and incorporating their unique capabilities into weapons systems; the result is unprecedented precision in navigation and targeting.

2. Early development of integrated circuits and their application to mission critical capabilities in target detection and identification as well as weapon guidance.

3. Development of aircraft technology which provides substantially improved capabilities in maneuverability, flight and fire control, and firepower.

4. Significant progress in the development and fielding of chemical warfare protection which enables combat units to better survive and fight in a chemical warfare environment.

5. Development of the carbon-carbon composite material nosetip for the TRIDENT D-5 re-entry vehicle.

The DOD total S&T Program effort in FY 1985 is about $6.0 billion, of which about $0.9 billion is allocated to Basic Research, $2.3 billion to Exploratory Development, and $2.8 billion (including $1.4 billion for the Strategic Defense Initiative) to Advanced Technology Development.

The DOD S&T Program is carried out by three performers. In FY 1984, more than half of the DOD S&T effort was performed by industry, about a third by DOD in-house laboratories, and the balance by universities. Each performer plays an important role in the overall DOD effort, and the strong interrelationships and synergisms among the three components of the scientific infrastructure yield a major return on this investment. In view of the strong interrelationship among the three performers, this report considers efforts in all three areas to identify DOD needs, existing activities that should be strengthened, and new initiatives which have been undertaken or are being considered. This report also describes the major bilateral and multilateral S&T arrangements with our allies.

Analysis of the DOD S&T Program indicates that:

- Many important S&T contributions are being made toward increasing the technological warfighting capability of defense systems.

- o S&T work being performed by industry, universities, and in-house laboratories is of high quality, scientifically sound, and vital to our national defense.

The maintenance of future U.S. S&T capabilities will, however, require:

- o Additional funding in several S&T areas.
- o Measures to correct a decline in the supply of scientists and engineers to perform necessary defense-related research, particularly in universities and in-house laboratories.
- o Upgrading of university and in-house laboratory research instrumentation and facilities to assure high quality research.
- o New approaches in the contracting process to simplify interactions among government laboratories, industry, and universities involved in the S&T Program.
- o Cooperation and collaboration with our allies to improve our S&T posture.

This report describes some of the programs which are under way to address these issues. In addition, the FY 1986 budget request addresses some of these concerns. Continuing Committee support of the Science and Technology Program is necessary to the nation's future defense capabilities.

CHAPTER II
DOD SUPPORT OF UNIVERSITIES

A. INTRODUCTION

Overview

The subject of this chapter is the role that universities play in sustaining and strengthening the U.S. science and technology base, the scope and nature of existing DOD programs that support universities in that role, and additional measures that DOD may take to enhance that support. Subsequent sections of this chapter will address the DOD role in the direct funding of university research (Section B), the upgrading of research instruments and equipment (Section C), and the use of fellowships and other "people-oriented" programs to encourage career choices into areas of particular importance to DOD (Section D). Specific recommendations and future plans are summarized in Section E.

Granted the importance of these issues to DOD, it must nonetheless be recognized that maintaining an adequate science and technology base is a national priority with important economic as well as military implications. Thus, DOD cannot be expected to solve the attendant problems alone. Solutions must be broadbased in nature, encompassing all relevant government agencies, the private sector, and the universities themselves. This chapter focuses, however, on the relationship between DOD and universities.

Role of the Universities

The university establishment plays a uniquely important role relative to the strength of the nation's science and technology base. The universities are the source of future scientists and engineers. In addition, the research contributions of academia to society are

enormous. In the post-World War II era, universities have conducted most of the fundamental research that has spawned the technological innovations on which much of our economy and national defense are based today. Universities contribute approximately 70 percent of the scholarly papers appearing in prestigious science and technology journals. In addition to generating scientific insight and knowledge which forms the basis of future technological innovation, university research activities provide an essential environment for the development of future scientists and engineers. These activities enrich the professional experience of faculty and graduate students engaged in the training of technical manpower. Thus, support of university research produces multiple payoffs of inestimable value to society.

The success of the academic teaching and research enterprise involves a number of factors. They include a creative, dedicated faculty, sufficient laboratory and support resources, and an adequate supply of students, both graduate and undergraduate. Within the framework of these criteria, a number of challenges are associated with maintaining and/or upgrading the nation's technical education and research capacity:

o Faculty Shortages in Technical Fields: A survey conducted by the American Society for Engineering Education (ASEE) indicates an overall engineering faculty vacancy rate of 8.5 percent in 1983, with vacancy rates in electrical and computer engineering at 9.7 and 15.8 percent respectively. These shortages are primarily due to industry demand for talent in these areas. This demand tends both to decrease the number of persons seeking advanced degrees in technical fields and to lure those persons who do go on for a Ph.D. out of academe. Industry currently offers significantly higher salaries and superior laboratory equipment.

o Decline of U.S. Citizen Participation in Graduate Programs: The number of engineering doctoral degrees awarded to U.S. citizens by U.S. universities declined steadily throughout the 1970s and early 1980s, producing a net decline of 42 percent between 1968 and 1982, while the number of advanced degrees awarded to foreign nationals almost tripled during this same period. Nearly half of the engineering Ph.D.s now awarded go to foreign nationals. Little is known about the employment plans of foreign science and engineering Ph.D.s, but about half return to their home country. Whatever their plans, however, they generally cannot obtain U.S. security clearances and are not available for direct DOD employment and may be restricted as to DOD related work in universities and industry.

The decline in the number of American citizens pursuing advanced degrees can be attributed to several factors. First, as previously mentioned, marketplace demand for engineers is such that attractive job offers, providing immediate return on a student's investment in education, are luring bachelor degree recipients into industry. In addition, financial support is less available to graduate students than in the past. In 1983, the U.S. Federal government supported only 20 percent of the number of fellowships in 1968. Of those supported in 1983, only 1,600 were in engineering and science.

Finally, it must be noted that, as a result of demographic factors, the total number of 22 year olds in the U.S. will decline by approximately 17 percent by 1990. The decline in student population, already evident in many parts of the country, commensurately shrinks the pool from which future science and engineering talent can be drawn. Thus, unless student career preferences change substantially, the U.S. will graduate fewer scientists and engineers rather than the increased numbers required to maintain national technological competitiveness.

o Decline of University Research Laboratories: Estimates ranging up to $2 billion have been proposed as a requirement for replacing obsolete university research instrumentation. Laboratory facilities, especially instrumentation necessary to conduct research aimed at expanding the U.S. technology base, are becoming increasingly expensive. Establishing and maintaining these facilities is a very costly proposition for such equipment items as advanced supercomputers, large particle accelerators, various types of analytical instrumentation, imaging devices, and automated design and manufacturing hardware. Such equipment, nonetheless, is crucial for the conduct of meaningful research in important areas of science and engineering, and for the training of students.

DOD Support for Universities

As one of the first Federal agencies to recognize the essential role that U.S. colleges and universities play in the maintenance of U.S. technological leadership, DOD has maintained a strong relationship with the academic community; this relationship predates World War II. Since technological leadership is an essential component of military superiority, DOD has a major stake in maintaining the strength of U.S. science and technology.

o Direct Funding of University Research: U.S. universities are a major factor in DOD technology base activities. Approximately one half of DOD's Basic Research (6.1) is performed at universities ($405 million out of a total of $840 million in FY84). Support for universities is not limited to funding for Basic Research. As an additional important benefit, the resulting university research programs are a major factor in addressing the problems of the universities that were discussed in Section A.2. By providing the opportunity to perform fundamental research at the forefront of science and engineering, university research programs help to create a professional environment that can

attract and retain faculty and students. Past studies suggest that, on average, each $1 million of research program provides full or partial financial support for approximately 10-15 graduate students. On that basis, DOD provided financial assistance for over 4000 graduate students through its university research programs in FY84. As will be shown in Section C of this chapter, roughly $75 million worth of instruments and equipment were purchased by universities in FY84 through DOD research programs (counting a $30 million per year Defense University Research Instrumentation Program (DURIP) discussed below).

The DOD-university relationship has received strong emphasis during the last decade. In constant dollars, DOD funding for the performance of basic research at universities grew at an average annual rate exceeding 9 percent during the period 1975 to 1984. This is far better than funding for DOD technology base activities as a whole, which is still below 1965 levels in real terms as noted by Secretary Weinberger's memorandum to the Services dated August 9, 1984. As in the past, universities can be expected to compete effectively for future growth in DOD technology base funds. In the memorandum referred to above, Secretary Weinberger requested real growth for the technology base in the Defense Guidance for the FY 1987-91 Five Year Defense Plan. DOD continues to support that position. A more detailed discussion of direct funding of R&D at universities is provided in Section B of this chapter.

o University Research Instrumentation: DOD recognized the nature of the university research instruments and equipment problem well before formal studies were initiated. As suggested above, the fraction of university research contracts devoted to the purchase of instruments and equipment has been increasing--reaching approximately $45 million per year in 1984. In addition, specially targeted funds of $30 million per year are provided for large equipment purchases through the Defense University Research Instrumentation Program (DURIP). The availability

of modern instruments and equipment improves the quality of university research and enables universities to compete more effectively with industry for scientists and engineers. DOD will continue to address instrumentation needs through its research contracts and through special programs such as DURIP and the newly proposed "University Research Initiative" program elements discussed below. However, DOD cannot and should not address this problem alone. In view of the scope and magnitude of the problem, it must be addressed over a period of years in an interagency-private sector context. DOD instrumentation programs are discussed in Section C of this chapter.

o University Research Facilities: Although concern has been expressed about the condition of university research facilities (e.g., laboratory buildings), the dimensions of the problem have not been quantified. DOD is currently assessing the nature and scope of this problem. Results will be made available to the Committee as they are received. Once again, this is a problem which must be addressed over a period of years in a national context.

o Education Programs: The three Services have initiated a number of special programs designed to attract exceptional candidates to graduate study and to university faculty careers in areas of science and engineering of particular interest to DOD. These programs include graduate fellowships, summer faculty programs, special faculty chairs, a newly established Navy Young Investigators program, and programs to enhance professional interaction between university scientists and engineers and their colleagues in DOD laboratories and in industry. When considered in the context of stable growth for the technology base, increased availability of modern equipment in university laboratories, and the growing emphasis on similar programs at other federal research organizations, these "people-oriented" DOD initiatives represent a significant supplemental incentive to attract exceptional students and faculty to areas of interest to DOD. Funding levels for these programs

will be increased with the availability of funds through the "University Research Initiatives" discussed below. Other relevant special DOD programs are designed to attract more women and minorities to science and engineering research, and to provide incentives for high school students to consider technical careers. Some of these special programs are discussed in greater detail in Section D of this chapter.

o "University Research Initiative" Program Elements: In FY86 DOD plans to establish new research program elements that will be focused exclusively on the DOD/university relationship. Total proposed funding for the new program elements is $25 million in FY86, and $50 million in FY87. Additional growth is anticipated in future years. Each of the Services and the Defense Advanced Research Projects Agency (DARPA) will implement programs within these program elements to meet the priorities of their specific relationships with the academic community. Although the specific mix will vary from Service to Service, graduate fellowships, support for young investigators, purchase of research instrumentation, and support of special research programs will be included in the total DOD program for these program elements.

o DOD/University Advisory Groups: DOD has long recognized the value of the academic community as a source of expert advice. The Department maintains communications with people in the academic community, as individual consultants and as members of numerous advisory committees, on programmatic issues at all levels. To insure more effective communication with the academic community, specifically focused on issues at the policy level, DOD established the DOD/University Forum in 1983. The Forum has provided a mechanism for continuous dialogue between DOD and the academic community on issues of mutual interest. One significant, direct outcome of the Forum's activities during the past year was the establishment of a policy on the transfer of scientific information. The resulting clarification of DOD

policy establishes an appropriate balance between the conflicting imperatives of national security and open scientific communications.

B. DIRECT FUNDING OF UNIVERSITY RESEARCH

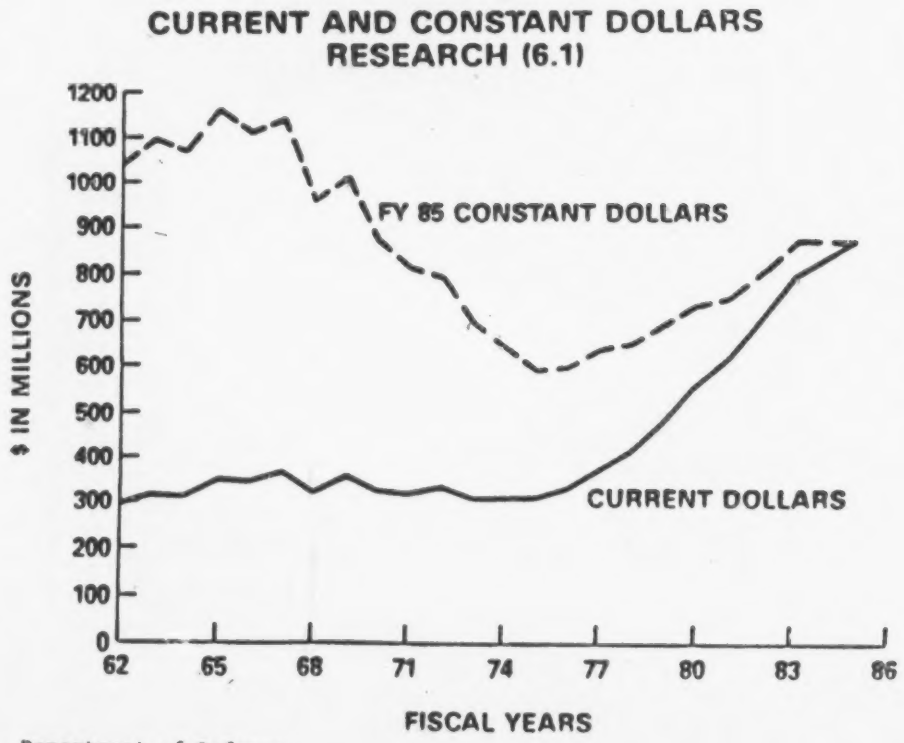
The Senate request for this DOD report on the technology base included the observation that "DOD investment in the technology base dropped by 40 percent from the mid-1960s to mid-1970s and today remains more than 30 percent below the mid-1960s level in real terms." This general pattern is illustrated in Figure B.1 which shows the history of DOD funding for basic research (6.1) since 1962. The corresponding funding history for exploratory development (6.2) is shown in Figure B.2.

During the past decade, DOD has taken major steps to reverse the past impact of the relative neglect of the technology base. As Figures B.1 and B.2 illustrate, funding in current dollars for both components of the technology base grew significantly during the late 1970s and early 1980s; nevertheless, neither component has returned to 1965 levels of support in real terms. In fact, in real terms, funding for exploratory development has been virtually constant for over a decade. In a memorandum to the Services dated August 9, 1984, Secretary Weinberger noted these facts and indicated that the Defense Guidance for the FY 1987-91 Five Year Defense Plan would request annual real growth in both components of the technology base. DOD still supports that position.

University research has been a major component of the growth in DOD technology base activities during the past decade. Table B.1 exhibits DOD 6.1 Research funds spent at or budgeted for universities by the Army, Navy, Air Force, and DARPA for the years FY74-86. Note that during the period FY75 to FY84 DOD spending for 6.1 Research at

FIGURE B.1

DOD SCIENCE AND TECHNOLOGY FUNDING TRENDS



SOURCE: Department of Defense

FIGURE B.2

DOD SCIENCE AND TECHNOLOGY FUNDING TRENDS

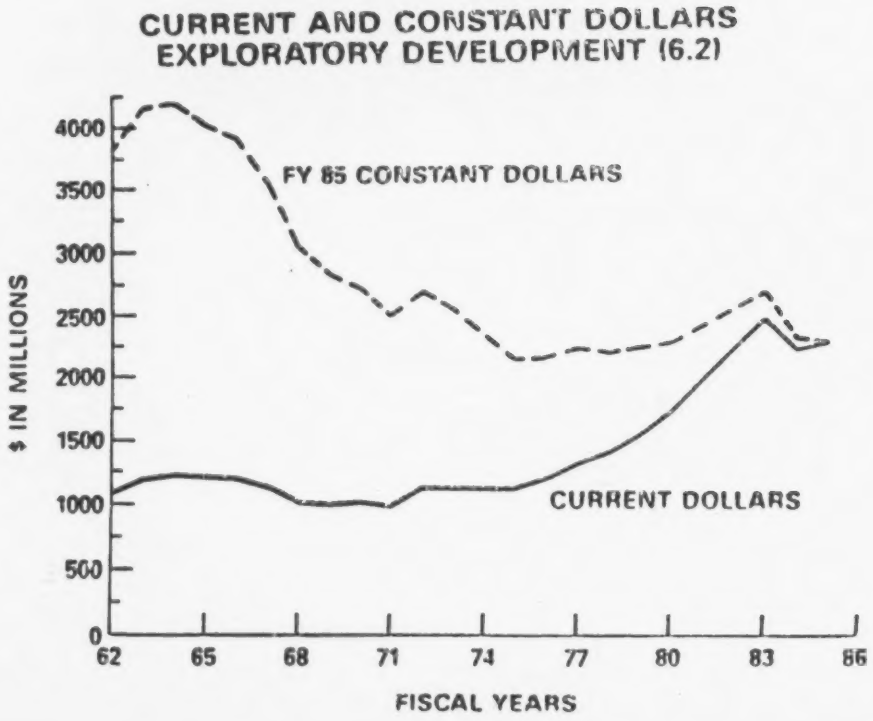


TABLE B.1

DEPARTMENT OF DEFENSE FUNDING FOR UNIVERSITY BASIC (6.1) RESEARCH, FISCAL YEARS 1974-86
(In millions of dollars)

Service	FY 74 Current	FY 74 Real	FY 75 Current	FY 75 Real	FY 76 Current	FY 76 Real	FY 77 Current	FY 77 Real	FY 78 Current	FY 78 Real	FY 79 Current	FY 79 Real	FY 80 Current	FY 80 Real
ARMY	13.7	27.9	13.4	25.0	19.0	33.7	23.7	39.6	28.1	43.8	32.0	45.9	38.1	50.1
AIR FORCE	23.2	47.3	22.9	42.6	28.2	50.0	41.0	68.6	49.5	77.1	46.4	66.6	55.3	72.7
NAVY	45.5	92.7	47.0	89.2	64.2	113.8	62.7	104.8	70.8	110.3	86.4	124.0	100.2	131.7
DARPA	21.9	44.6	19.4	36.1	19.1	33.9	18.7	31.3	17.9	27.9	21.0	30.1	19.8	26.0
TOTAL	104.3	212.4	103.6	192.9	130.5	231.4	146.1	244.3	166.3	259.0	185.8	266.6	213.4	280.4

Service	FY 81 Current	FY 81 Real	FY 82 Current	FY 82 Real	FY 83 Current	FY 83 Real	FY 84 Current	FY 84 Real	FY 85* Current	FY 85* Real**	FY 86* Current	FY 86* Real**
ARMY	46.5	55.9	56.1	63.5	71.4	77.7	80.6	84.6	83.8	83.8	87.9	83.8
AIR FORCE	63.4	76.2	71.5	81.0	90.3	98.3	112.1	117.6	119.1	119.1	135.0	128.7
NAVY	115.0	138.2	142.3	161.2	152.2	165.6	158.1	165.9	176.1	176.1	198.8	189.5
DARPA	27.3	37.8	39.4	44.6	46.4	50.5	53.9	56.6	42.7	42.7	43.4	41.4
TOTAL	252.2	303.1	309.3	350.3	360.3	392.1	404.7	424.7	421.7	421.7	465.1	443.4

* Projections

** Forecast for inflation is based on CBO projection

SOURCE: Army Deputy Chief of Staff Research Development and Acquisition, Office of Naval Research, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, (Constant 1985 Dollars Calculated using GNP Implicit Price Deflator)

universities grew at a real annual rate of 9 percent--higher than the annual growth of the total DOD 6.1 Research program.

Table B.1 shows only the DOD Research (6.1) funds going to universities. A similar break out of the university component of DOD Exploratory Development (6.2) funds is not readily available. To provide a point of reference, in FY83 a total of $102.3 million in DOD Exploratory Development (6.2) contracts went to universities as compared to $360 million for Research (6.1) contracts and grants. It should be noted that DOD funding for universities is not limited to Research and Exploratory Development.

DOD sponsors research and development at universities to ensure the advancement of fundamental knowledge that is necessary, in the long run, to maintain technological superiority. However, as will be noted in Sections C and D of this chapter, university research programs have other important impacts that have a significant effect on the future supply of scientists and engineers by attracting and retaining potential faculty and students, i.e., support for fundamental scholarly research, purchase of modern instrumentation, and financial support for thousands of graduate students.

C. INSTRUMENTATION

Background

Instrumentation is an essential element of modern research. Modern instruments with qualitatively superior capabilities for analysis and measurements can open new fields of scientific inquiry. In many scientific areas, access to the most advanced scientific instrumentation determines in large measure the extent to which scientists can work at the cutting edge of their field.

There has been a growing realization among the scientific and university communities, and in state and Federal government agencies and the Congress, that the condition of research instrumentation in U.S. universities declined significantly during the 1970s. The Association of American Universities (AAU) in a report to the National Science Foundation (NSF) in June 1980 concluded that the equipment being used in the top ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories, an additional factor in the attraction of potential faculty to industry.

A more recent survey by the NSF emphasizes this point. Data for the research instruments surveyed by the NSF were collected from a stratified probability sample of 43 universities selected from the 157 largest academic R&D performers. Inventories for all existing research equipment were obtained from institutions' central record-keeping systems and were sent to department heads for verification. More than 90 percent of both department heads and investigators responded. According to the survey, 25 percent of U.S. academic research equipment is classified as obsolete by the scientists who use it, whereas only 16 percent is characterized as being state-of-the-art. Results of the survey, based on 22,300 items in a 1982 research equipment inventory in computer and physical sciences and engineering, are summarized below:

Status	Age	Purchase Price
2% not in use	45% 1-5 years	58% $10,000-$24,999
16% state-of-the-art	20% 6-10 years	31% $25,000-$74,999
26% obsolete	31% over 10 years	11% $75,000-$1M
56% other		

The NSF study provides a more detailed breakdown by research area.

In terms of its capability to enable investigators to pursue their major research interests, department heads rated the adequacy of their research equipment as: excellent--8 percent; adequate--46 percent; and

insufficient--46 percent. More than 90 percent reported that "important subject areas" of research could not be performed in their units because of lack of needed research instrumentation. Thus, the state of university research instrumentation represents a national problem which deserves serious attention by government, private industry, and the university research community. The gap between the present university research instrumentation capability and that required to ensure maximum productivity by creative and innovative researchers has been estimated to be at least a billion dollars.

The instrumentation problem has been building for a period of 10 to 15 years. It reflects a combination of economic factors and funding patterns:

- The cost of equipment has risen considerably faster than inflation.
- The system of one to three year contracts in the $50,000 to $100,000 per year range with individual investigators tends not to lend itself to the purchase of equipment costing more than $50,000.
- Rapid advances in instrumentation technology are rendering research equipment obsolete at an ever increasing rate.

DOD Instrumentation Programs

Through its contacts with university researchers, DOD became aware of the instrumentation problem well before formal studies of the situation were initiated. DOD has encouraged investigators to include more of their equipment needs in proposals and emphasized that DOD does not set artificial limits on the amount of money that could be requested for instrumentation. This approach has been adequate to deal with

equipment needs up to the $50,000 range. However, there was a clear need for new money dedicated to the purchase of some of the more expensive items required to modernize university laboratories. These funds were provided in FY83 through the Congressionally approved DOD-University Research Instrumentation Program (DURIP).

DURIP provides $150 million over five years for university research equipment. Each of the three Services is programmed to spend $10 million per year. To date, $90 million has been spent on 652 awards going to 152 institutions in 47 states and Washington, D.C., Guam, and Puerto Rico. DURIP is having a major impact on the equipment needs of researchers doing work of interest to DOD. It will not, however, solve the whole university instrumentation problem. In the first year of DURIP, DOD received 2,500 proposals representing requests for $646 million worth of equipment. While some of these requests were for equipment to support research in areas not funded by DOD the first year response is nevertheless an impressive qualitative measure of the needs of the universities.

As already mentioned, DURIP is the most visible, but not the only, DOD response to the university instrumentation problem. In addition, each of the Services and DARPA have encouraged current and prospective contractors to make their equipment needs known so that many of the less expensive items can be purchased as an integral part of research program funding:

- The percent of the Army Research Office (ARO) contract program devoted to instrument purchases has increased steadily over the last decade so that in FY85 such purchases will represent approximately $6 million of the ARO contract research program.

- University related equipment purchases associated with the Office of Naval Research's Contract Research Program grew from $11.2 million in 1979 to $16.6 million in 1984.

- During the decade from 1975 to 1985, equipment funding by the Air Force Office of Scientific Research, during the normal course of its sponsored research program, increased from $2 million to $8 million per year.

- In general, 10 to 20 percent of DARPA's university program funds have been utilized for equipment. In 1981, DARPA initiated a modernization program targeted on obsolete equipment and the need for greater computational power. From 1981 to 1984, equipment purchases by universities using DARPA funds increased from $6.7 million to $16.8 million per year.

In certain cases, where the equipment necessary for major research efforts has been costly, specific provisions have been made for extraordinary purchases. Examples include the purchase of large main frame computers, semiconductor processing lines, molecular beam epitaxy and analysis chambers and ARPANET computational and communication facilities by DARPA, and an ongoing Office of Naval Research program to refurbish selected research vessels.

In FY84, in addition to the $30 million of special DURIP purchases, the three services and DARPA purchased over $45 million worth of research instruments and equipment for universities in connection with their ongoing research contracting activities.

D. EDUCATION PROGRAMS

Background

The ability of the United States to maintain superiority in broad areas of science and technology will largely depend on how well universities and colleges are able to recruit and train new scientific and engineering talent. Declining numbers of doctoral degrees awarded to U.S. citizens, coupled with the shortage of faculty in technical fields and the lure of industry employment, make the universities' task a difficult one.

The U.S. defense industry is a major employer of the scientists and engineers trained by U.S. universities and colleges. According to a recent National Science Foundation (NSF) study, the percent of U.S. engineers employed in defense activities will increase from 12 percent in 1982 to 15 percent in 1987. In 1982, DOD alone employed 105,000 engineers and scientists (3.6 percent of the national total). The NSF study projects rapid growth and shortages exceeding 10 percent of the workforce (by 1987) in disciplines particularly important to DOD: aeronautical engineers, computer specialists, and electrical/electronic engineers. This general conclusion is reinforced by projections of the American Electronics Association that predict an annual growth rate of 10.6 percent in the demand for electrical engineers through the late 1980s and a 16.5 percent growth rate in the demand for computer engineers.

Granted the importance of these trends to DOD, it must be emphasized that DOD and the defense industry are important but not dominant factors in the employment of scientists and engineers. Solutions must involve all relevant government agencies and the private sector.

The prospects for attracting greater numbers of outstanding students into careers in science and engineering in DOD are clouded by a number of important factors:

- Due to demographic factors, the number of students graduating annually from U.S. high schools during the 1980s is expected to drop significantly (approximately 17%). Together with the decreasing percentage of students studying mathematics and science, this trend is likely to have a major effect on the pool of young people who can be attracted into technical careers.

- High vacancy rates are reported for high school teaching positions in mathematics and the physical sciences. The number of people preparing to teach in these areas has decreased markedly.

- The number of Ph.D.s in engineering awarded to U.S. citizens by U.S. universities declined steadily throughout the 1970s and early 1980s, with a net decline of 42 percent between 1968 and 1982. Nearly half of all engineering Ph.D.s now go to foreign nationals. As indicated earlier, foreign engineering Ph.D.s, even if they remain in the U.S., generally cannot obtain U.S. security clearances and are thus not available for direct DOD employment. Reasons for the decline in U.S. citizens receiving graduate degrees include the lure of industry with existing pay differentials, the increasing cost of graduate school, and the decline in federal financial assistance.

DOD Education Programs

During the past decade, DOD has initiated numerous "people-oriented" programs designed to increase the supply of qualified technical personnel, both uniformed and civilian, and to attract exceptional candidates into careers in areas of particular importance to DOD. The complete set of programs is extremely diverse, ranging from secondary school level through undergraduate and graduate school. Some are designed for postgraduates and university faculty. Some relevant DOD programs are listed in Table D-1, including a number of programs that are supported with funds other than RDT&E funds. Additional information on selected programs will be provided below.

It is important to recognize that the formal programs listed in Table D-1 and those discussed below are supplemental to DOD's basic research programs. In addition to meeting important DOD technology base requirements, the direct funding of university research represents DOD's largest single education program. For example, a Navy study conducted in 1980 indicated that the Office of Naval Research (ONR) supported an estimated 2,200 graduate students (fully or partially) through its 6.1 contract research program. This study and similar estimates by others suggest that, on average, a million dollars of 6.1 university research funding provide financial support for approximately 10-15 graduate students. On that basis, the DOD university research program provided financial assistance for well over 4000 graduate students in 1984. In addition, the combination of research contracts and instrumentation programs provides a university research environment that is essential to retain university faculty and to attract graduate students.

DOD reaps several benefits from its supplemental support of science and engineering education. First, the programs attract highly-qualified students and support their training in areas of interest to DOD. Second, fellowship support increases the number of doctoral students who

TABLE D.1

DOD SCIENCE AND ENGINEERING EDUCATION PROGRAMS*

SPONSOR	PROGRAM TITLE
ELEMENTARY & SECONDARY	
ARMY	Junior Science and Humanities Symposium Science and Engineering Fair Program Research and Engineering Apprenticeships Uninitiated Introduction to Engineering International Mathematical Olympiad Armed Forces Orientation in Engineering
NAVY	Research and Engineering Apprenticeships Pre Co-Op Program Navy Science Awards Program
AIR FORCE	Precollege Technical Orientation Research and Engineering Apprenticeships Uninitiated Introduction to Engineering
UNDERGRADUATE	
ARMY	ROTC - Hi Tech Scholarship Emphasis Co-Op Lab Employee Educational Program
NAVY	ROTC - Science and Engineering Program Co-Op Education Program Federal Junior Fellowship Program
AIR FORCE	Airman Education and Commissioning Program ROTC - Science and Engineering Scholarship Emphasis (85% for S&E Students) AF Institute of Technology Undergraduate Engineer Conversion Program College Senior Engineering Program (CSEP)
GRADUATE	
ARMY	Graduate Contract Research Programs Graduate Programs in computer science, electronics, modern optics, hypersonic aero-mechanics and aero-dynamics, and biogenetic engineering Graduate Programs at Centers of Excellence in Rotary Wing Technology

* Funded from various DOD sources, not limited to RDT&E funds. Programs which support the voluntary education of uniformed personnel are not included.

TABLE D.1 (Continued)

NAVY	Office of Naval Research-Graduate Contract Research Program Co-Op Education Program Graduate Programs in electrical engineering, computer sciences, naval architecture, applied physics, material sciences and mechanical and aerospace engineering Military Graduate Education Programs
AIR FORCE	Graduate Contract Research Programs Graduate Programs in thermionic engineering, composite structures, aircraft propulsion and manufacturing sciences
SPECIAL PROGRAMS	
ALL SERVICES	Historically Black Colleges Summer Faculty Research and Engineering Program Equipment Grants/Research Instrumentation Post Graduate Fellowships
ARMY	Summer Associateship for High School Science and Mathematics Faculty
NAVY	ONR Young Investigators Program

then have the potential to train other students. Third, training programs provide a pool of recruits for the various DOD RDT&E programs. Finally, the programs provide a variety of intangible benefits ranging from the expansion of professional contacts and rapport with the various DOD laboratories to the generation of interest and excitement in science and mathematics at the elementary and secondary school levels. Highlights are provided below for selected programs.

HIGH SCHOOL APPRENTICESHIP PROGRAM

DOD established the DOD Science and Engineering Apprenticeship Program for High School Students in 1981 with the objective of encouraging and supporting careers in science and technology. The program has three major purposes: one, to stimulate stronger interest in careers in science and engineering among high school students; two, to establish individual student/mentor relationships between students and active researchers; and three, to strengthen the nation's efforts to recruit and sustain careers in science and engineering, consistent with affirmative action program goals and objectives. Although the apprenticeship program applies most directly to DOD laboratories, it can also be used by the service research offices through their contract-supported principal investigators at universities.

SELECTED ARMY EDUCATION PROGRAMS

The Army has programs in science, mathematics, and engineering education at the secondary, undergraduate, graduate, and postgraduate levels.

Pre-College Education Programs. (i) The Junior Science and Humanities Symposium (JSHS) Program exposes 7,500 secondary students each year to leading scientists in the academic, industrial, and government communities. (ii) 60,000 students annually participate in

more than 280 regional, state, and International Science and Engineering (ISEF) Fairs. (iii) Eight talented students are selected competitively from over 400,000 high school participants to represent the U.S. at the annual International Mathematical Olympiad (IMO). (iv) The Uninitiated Introduction to Engineering (UNITE) program provides a select group of socially - and economically - disadvantaged high school students with four weeks of summer instruction and guidance by cooperating universities and Army laboratories. (v) The Research and Engineering Apprenticeship Program (REAP) can extend over several summers and offer mentor/apprentice training for disadvantaged youngsters by university professors. (vi) An intensive, four-week program involving digital logic, microprocessors, robotics, and programming is available in Computer Related Engineering and Science Studies (CRESS).

Undergraduate Educational Programs. The Army's Reserve Officer Training Corps (ROTC) program includes 12,000 students at over 300 universities; recent selections have emphasized science, mathematics, and engineering. Also, the Army has a very active co-op work/study arrangement with many colleges and universities.

Graduate Level Educational Program. Over 800 research contracts with universities throughout the United States support, as a byproduct, many graduate students working on the contracts. In addition, last year, the Army awarded 35 graduate fellowships in computer science, electronics, modern optics, hypersonic aeromechanics and aerodynamics, and biogenetic engineering under the Army Fellowship Program.

Special Educational Programs. Seventeen historically black colleges (HBC) are involved in a special Army effort to sponsor mathematics, engineering, and science research at HBCs; about $1.4 million per year is involved. The Summer Faculty Research and Engineering Program (SFREP) offers 10-week summer appointments in Army laboratories to selected university faculty members; 24 Army

laboratories participate. The Army has a similar program for high school science and mathematics faculty that involved 90 teachers in first summer of the program.

Postdoctoral Program. Working with the National Academy of Sciences, the Army has about 55 National Research Council Fellows working in several Army laboratories on postdoctoral research. This program is available to new doctoral graduates as well as to more senior researchers at colleges, universities, non-profit research institutes, etc. The program fosters interaction between Army and civilian scientists and engineers, and it has resulted in Army recruitment of many capable young researchers.

SELECTED NAVY EDUCATION PROGRAMS

The Navy supports science and engineering education at all levels. Several of these programs are run by or in conjunction with Navy laboratories because of their direct need for highly trained personnel.

At the pre-college level, the Navy has programs for hiring science and engineering apprenticeship students at laboratories in the summer. ONR encourages university contractors to involve high school students on research projects. In FY 1983, 335 students were supported under these programs. In addition to participating in regional and state science and engineering fairs, the Navy offers scholarships and other awards in the Navy National Science Awards Competition and the International Science and Engineering Fair.

At the college undergraduate level, the Navy supports three programs: the ROTC Science and Engineering Program, the Co-op Education Program, and the Federal Junior Fellowship Program. In FY 1983, these programs had approximately 7,300 participants.

The Navy supports several significant educational programs at the graduate level. These include the ONR Graduate Fellowship Program, the Co-op Education Program, and the Military Graduate Education Program. The ONR Graduate Fellowship Program is directed toward increasing the supply of U.S. citizens trained in areas of science and engineering of particular importance to current and future naval technology. Started in FY 1982, this program currently supports 40 new fellows per year, who pursue doctoral studies in electrical engineering, computer science, naval architecture, applied physics, material science, mechanical and aerospace engineering, mathematics, and oceanography. Funding for this program is planned to grow to over $4.5 million by FY 1989, thereby enabling the selection of 50 new ONR fellows per year. This represents a 20 percent increase over the present level.

The Navy supports postdoctoral training at Navy laboratories and under research contracts at universities. The Navy awards Postdoctoral Cooperative Research Associateships through the National Research Council. These associateships can be used at the Naval Research Laboratory (NRL), Washington, D.C. and the Naval Ocean Research and Development Activity (NORDA), Bay St. Louis, MS. These competitive awards provide opportunities for doing basic and applied research on-site at NRL or NORDA. A program sponsored by the Office of Naval Technology provides similar opportunities for thirty postdoctoral research fellows each year at the other Navy laboratory centers.

In addition to student support, the Navy provides faculty support. Under the Summer Faculty Research Program, science and engineering faculty members from universities and colleges spend ten weeks in the summer conducting research at Navy laboratory centers. For the last three years, over one hundred university faculty members have entered this program each summer. Participants work with professional peers on research tasks of mutual interest. Follow-up programs have been found to occur between the laboratories and the faculty members in

57-279 O - 87 - 43

about 30 percent of the cases. A second program supports research chairs at the U.S. Naval Academy, the U.S. Naval Postgraduate School, the Massachusetts Institute of Technology, and the University of Michigan. The Navy also finances visiting professorships to the U.S. Naval Academy and the U.S. Naval Postgraduate School.

ONR plans to initiate a new program in FY 1985 to identify and support exceptional young investigators who are in tenure track positions at U.S. universities. The ONR Young Investigator Program is designed to encourage younger researchers to take an active role in naval research. ONR will invest $2.0 million in this program in FY 1985.

In addition to its formal educational programs, the Navy also has the Historically Black Colleges (HBC) Council. The Council is an officially established ONR body whose primary purpose is to facilitate relationships between HBC institutions and ONR that may eventually lead to greater HBC participation in the ONR Contract Research Program (CRP). As a result of this and other efforts, ONR spent $2.4 million with HBCs in FY 1984.

SELECTED AIR FORCE EDUCATION PROGRAMS

The Air Force is supporting science and engineering education through officer commissioning and graduate education programs, civilian personnel programs, and a number of special programs associated with basic research.

Under its officer commissioning programs, in FY 1985 the Air Force will provide 7,500 ROTC scholarships, of which 85 percent are for S&E students. It will also enroll about 400 airmen in the Airman Education and Commissioning Program, of which about 90 percent will be S&E students, and 75 students in the College Senior Engineering Program. In FY 1985, about 525 officers will enter graduate S&E programs.

The Air Force Laboratories, Centers, and Product Divisions also support programs to: (1) introduce high school students to Air Force technical careers; (2) employ undergraduate S&E students in co-op, stay-in-school, and summer hire programs; and (3) support the technical upgrading of civilian S&E employees through short-term and long-term full time training programs.

At present, about 60 percent of the Air Force basic research program is under contract at universities. This research supports an estimated 1,000 to 1,200 graduate students through research assistantships. In addition to this general support, AFOSR and the Air Force laboratories provide research and educational opportunities for graduate students, post doctoral scientists and engineers, and university faculty through special programs that support research on problems of interest to the Air Force.

The Air Force Office of Scientific Research (AFOSR) supports four graduate student assistantship programs that are focused on research areas of critical interest to the Air Force. The Air Force Thermionic Engineering and Research Program (AFTER) is focused on microwave tube research, a technology that electrical engineers supporting the vast consumer electronics industry have largely vacated. The Advanced Composite Structures Program is aimed at attracting students to research in composite structures and composite mechanics. The Air Force Research in Aircraft Propulsion Technology Program (AFRAPT) has the objective of attracting students to research in aircraft propulsion technology. The Manufacturing Sciences Program has the objective of attracting students to research in manufacturing techniques associated with aerospace vehicle assemblies. Total funding for these four programs increased from $2.5 million in FY 1982 to $4.44 million in FY 1985.

AFOSR supports two programs which bring university faculty members and graduate students into Air Force laboratories for ten weeks during

the summer. The Summer Faculty Research Program (SFRP) is designed to develop the basis for continuing research of interest to the Air Force at the faculty member's institution. In addition to the ten week summer research program, funding is also provided to allow about 50 percent of the researchers (on a competitive basis) to continue the research at his or her home institution. The Graduate Student Summer Support Program (GSSSP) allows outstanding graduate students to spend ten weeks at an Air Force laboratory conducting research while accompanying faculty members selected under the SFRP. Funding for these programs increased from $1.5 million in FY 1982 to $4.4 million in FY 1985.

The Air Force supports several programs which allow postdoctoral scientists and engineers to spend a year conducting research at Air Force laboratories on problems of their own choice that are compatible with research interests of the sponsoring laboratories. The Air Force Systems Command/National Research Council Resident Research Associateship Program and the University Resident Research Program are supported by AFOSR but with researchers placed at various participating laboratories. The Air Force Geophysics Laboratory and the Air Force Weapons Laboratory also support, respectively, the Geophysics Scholar Program and the Weapons Laboratory Scholar Program within their own laboratories. Total funding for these programs increased from $1.6 million in FY 1982 to $2.9 million in FY 1985.

AFOSR is engaged in a special initiative utilizing workshops and focused advertising to make Historically Black Colleges (HBCs) aware of opportunities in Air Force research and development, and to recruit faculty members and graduate students from HBCs for participation in the SFRP and GSSSP. In addition, under a grant from AFOSR, the Tuskegee Institute is conducting a summer research apprenticeship program for minority high school students.

E. RECOMMENDATIONS AND FUTURE PLANS

Funding of University Research

Significant real growth of the DOD technology base is required to ensure the advancement of fundamental knowledge necessary, in the long run, to maintain military and economic parity through technological superiority. It must be noted that funding for university research also addresses many of the problems associated with the future supply of scientists and engineers by creating a more attractive academic environment for both faculty and students, providing financial assistance for graduate students, and supporting the purchase of modern instrumentation.

- The Congress should authorize and appropriate the President's FY 1986 budget amounts for the DOD technology base at the requested level.

- Congressional approval for the FY 1986 budget should include the establishment of "University Research Initiative" program elements, with funding at $25 million in FY 1986, devoted exclusively to university programs.

- The current Defense Guidance specifies real growth for the Research and Exploratory Development programs for the years 1987-1991. This growth should be viewed as the minimum growth rate for the direct funding of R&D that is required to restore the health of the technology base. Additional funds should be provided to exploit technological opportunities and to support special programs that supplement and leverage the direct funding of research.

- Funding for the new "University Research Initiative" program elements should be increased to a total of $50 million in FY 1987. DOD should seek additional growth in future years.

- Additional funding beyond the base program described above, if available, would be used by the Services and DARPA in areas that would provide significant leverage for the base level of DOD research funding. To give but one example, the conduct of research at the frontiers of science and engineering requires access to the most advanced numerical and symbolic computational facilities. Providing DOD contractors with access to such facilities would significantly increase their productivity in many key research areas.

Research Instrumentation

- As documented in Section C, in addition to the specially targeted $30 million per year Defense University Research Instrumentation Program (DURIP), a very significant fraction of the funds provided to universities through DOD research contracts and grants is targeted for the purchase of research instruments and equipment (roughly $45 million in FY 1984). DOD will continue to emphasize such purchases as an integral part of its contract research program.

- If approved by the Congress, the purchase of research instruments, either directly or through special research programs, will be one of the potential uses for funds in the new "University Research Initiative" program elements.

- DOD will continue its highly successful DURIP program to update university research instrumentation. Funding for this program is currently scheduled to expire after FY 1987. The magnitude of the response to the DURIP program has confirmed the perception that there is a substantial need for modern instruments in university research laboratories. DOD cannot and should not address this problem alone. The problem should be addressed in an interagency context.

Research Facilities

- DOD has an obvious interest in the condition of the research facilities available to the universities who play an essential role in DOD technology base programs. A separate study is currently under way to determine the nature and scope of this problem for DOD contractors. Preliminary studies conducted by others suggest a problem of great magnitude. Once again, DOD cannot and should not address the problem alone. The need for a multi-year, interagency approach is even greater in the case of facilities.

Education Programs

- As documented Section D, the DOD Services support a variety of programs designed to attract future scientists and engineers at all levels, ranging from high school to postgraduate study. Additional programs have been established to attract bright young scientists to academic careers and to encourage professional interaction between university scientists and engineers and their colleagues in DOD and industrial laboratories.

CHAPTER III

DOD IN-HOUSE LABORATORIES

A. INTRODUCTION

This chapter addresses factors essential to the effective performance of the Department of Defense in-house laboratories. Its aims are threefold:

- To ensure a current understanding of the roles and posture of the laboratories.
- To address representative issues critical to the vigor of these laboratories.
- To highlight approaches the DOD is using to better ensure the maintenance and development of technical skills in its laboratories.

The perspective is one of overview; the topics are highly selective. Individual laboratories are not discussed. Resource breakouts are kept to a minimum. The objective is to provide information for the Congress in an orderly form to highlight areas of action conducive to ensuring a vigorous defense science and technology community.

B. UNDERSTANDING THE LABORATORIES

Understanding the DOD laboratories is an essential part of actions to address current and future defense capabilities. From this understanding can come change which will assist the laboratories in meeting their vital roles. The current atmosphere of reduced U.S.

direct involvement in military conflicts offers an opportunity to introduce improvements into the laboratories with minimum disruption of critical activities. The high stakes involved in our international technological markets and in the national security competition with the Soviet Union make it essential that increased attention be given to:

- Better ensuring the relevance and quality of the work in the laboratories.
- Improving staff and their facilities and equipment.
- Maintaining and improving the quality of technical leadership and management of these laboratories.
- Providing this leadership the authority and flexibility to effectively manage their resources.

C. PROFILE

There are approximately 72 DOD in-house laboratories, some large, some small, performing work in the physical, life, and behavioral sciences in support of military and civil works programs of the DOD. They constitute a large investment of dollars and manpower. The acquisition cost of real property and equipment exceeds $4.0 billion. Some 27,500 scientists and engineers conduct the diverse activities of the laboratories. An annual cash flow greater than $7.9 billion is involved, with nearly two-thirds of that being research and development. About 40 percent of these R&D funds are retained by the laboratories to carry out work directly with their own personnel, the remainder being contracted largely to industry and universities. The non-R&D portion of the laboratories' funds are predominantly procurement monies that are used to achieve first acquisition of material systems and associated procurement support activities.

D. ROLES

The DOD in-house laboratories have become increasingly important to DOD RDT&E and Procurement programs. Recent emphasis in these areas increases the cruciality of their performance. As major participants in the technology base and in the systems development and acquisition process, the laboratories must undertake workload to respond to national need and programming to:

- Direct substantial R&D effort toward the longer term technological opportunities and deficiencies--particularly through the vitalization of our technology base, the stimulation of prototyping and the use of mature U.S. and Allied technology, and the reduction of intelligence asymmetry and "technological surprises" in the face of a determined and well supported Soviet competition. This effort includes the monitoring, assessment, and evaluation of the science and technology base in terms of potential for military utilization.

- Provide engineering support to obtain lower cost for weapon systems and equipment in production, operation, and support.

- Conduct advanced development and full-scale engineering development as appropriate.

- Achieve weapons equipment improvements which reduce the impact of projected manpower constraints.

- Provide scientific and engineering services and support to the operating forces.

- Develop, operate, and maintain major R&D facilities to meet specific needs unique to national defense requirements.

- Conduct mission analysis to identify system needs and deficiencies, both current and future, and determine preferred courses of action.

In accomplishing these functions, it should be stressed that a primary purpose of the laboratories is to develop and nurture new technologies to support their missions. The importance of this role for the in-house laboratories--the extension, development, and constant improvement of the technology base underlying all future development efforts--is fundamental. Unfortunately, this function is easily lost in the flood of product improvements, "quick-fixes" and concern over current operational problems--often the result of previous neglect to the technology base. It is imperative that the laboratories remain on the cutting edge of technologies critical to future military systems, both through their own research programs and through fostering and synergizing the results of such research, in the academic and industrial segments of the research community.

Further underscoring the need for competent and creative DOD in-house laboratories are reasons such as the following:

- The maintenance of national competence during peacetime, as well as times of conflict, in those areas of technology peculiar to military needs.

- The necessity for maintaining a continuity of effort, free from excessive commercial pressures, directed toward the conception and evolution of advanced military systems and equipment.

- The need for competent in-house skills to carry concepts through the planning, programming, and budgeting process for support of direct in-house work and for potential contract placement, monitoring, and assessment, and the ability to execute R&D as appropriate.

- The requirement to have available to the DOD a fast-reaction capability to solve critical, immediate problems that arise in connection with existing operational weapons systems and other items, and when unexpected combat situations are encountered (such as some of those experienced in Southeast Asia and the Middle East).

Figure 1 shows ten major goals and objectives for the DOD in-house laboratories. Secondary roles include such things as providing a training base for junior and senior military personnel, and for civilians who can transfer to headquarters and to nonlaboratory DOD elements involved in science and technology activities.

Figure 2 shows the major required in-house functions for DOD R&D and associated organizations involved in fulfilling their roles. Accordingly, the DOD has nurtured its laboratories for several decades to establish an environment conducive to the exchange of technical information and the exercise of judgment tailored to effective overall management. The bonds integrating the laboratories with a wide array of DOD research, development, and acquisition activities are complex and important.

FIGURE 1

DEPARTMENT OF DEFENSE
GOALS AND OBJECTIVES FOR RESEARCH AND DEVELOPMENT LABORATORIES

1. Ensure the maintenance and improvement of national competence in technology areas essential to military needs.

2. Avoid technological surprise and ensure technological innovation.

3. Maintain a continuity of effort, free from excessive commercialization pressure, directed toward the conception and evolution of advanced military material and support technologies.

4. Pursue technology initiatives through the planning, programming, and budgeting process; allocate work among private sector organizations and government elements.

5. Act as principal agents in maintaining the technological base of DOD.

6. Provide material acquisition and operating system support.

7. Have available a fast-reaction capability to solve critical, immediate technical problems that arise when unexpected operational situations are encountered.

8. Stimulate the use of technical demonstrations and prototypes to mature and exploit U.S. and allied technologies.

9. Carry out activities having high technological risk or requiring intensive resource investment not available from the private sector.

10. Interface with the worldwide scientific community; provide support to other government agencies.

SOURCE: Department of Defense

FIGURE 2

MAJOR DEPARTMENT OF DEFENSE RESEARCH AND DEVELOPMENT FUNCTIONS

1. BASIC RESEARCH - Increasing knowledge and understanding in fields directly related to long-term national security needs.

2. EXPLORATORY DEVELOPMENT - Developing and evaluating technical feasibility for solving broadly defined problems.

3. ADVANCED DEVELOPMENT - Systematic knowledge application toward production of useful materials, devices, systems, or methods.

4. ASSESSMENT OF SCIENCE AND TECHNOLOGY BASE - Continuous monitoring, assessment, and evaluation in terms of potential for military utilization.

5. MISSION ANALYSIS - Identification of systems needs and deficiencies, current and future, and determination of preferred courses of action.

6. CONCEPT EXPLORATION/SYSTEM VALIDATION - The feasibility study, development, and refinement of system concepts in response to military needs.

7. FULL-SCALE ENGINEERING DEVELOPMENT - Hardware engineering for Service use prior to approval for procurement.

8. ENGINEERING IN SUPPORT OF PRODUCTION - Periodic testing of production hardware, failure analysis, establishment of corrective actions, technical documentation control, and review of proposed production changes.

9. TEST AND EVALUATION - Determination of whether systems meet established performance objectives prior to release to production.

10. MAJOR RDTE FACILITIES - Facilities to meet specific needs unique to national defense requirements.

11. SERVICES AND SUPPORT TO OPERATING FORCES - Includes installation and testing, design deficiency correction, system improvement/retrofit, training, and logistic support.

SOURCE: Department of Defense

E. ISSUES

DOD laboratory management involves several issues which in the end merge into a single issue--how can the DOD increase the effectiveness of its personnel and funding resources for laboratories. This is, of course, much too large an issue to be taken in one bite. Ths single problem, insofar as the laboratories are concerned, may be viewed as consisting of the following primary issues:

- o Achieving balance between available manpower and tasking within funding constraints.
- o Obtaining adequate flexibility for management.
- o Ensuring proper degree of intra- and inter-laboratory coordination.
- o Providing appropriate performance incentives and work environment.
- o Developing a program structure conducive to realization of goals.
- o Maintaining a proper mix of in-house and contract R&D.
- o Developing adequate mechanisms for performance assessment.
- o Changing priorities
- o Making long-term projections

These and other similar interests lie at the heart of the maintenance and development of the laboratory infrasturcture and the

general health of the defense technology establishment. What is needed is full recognition that continuous concerted attention and assistance is essential.

F. CURRENT SITUATION

The DOD has been and is developing approaches that will further improve management of its laboratories. These actions are in various stages of advancement, some establishment, some evolving. Included in these actions are two dominant interrelated thrusts:

- The establishment in 1979 of the DOD Laboratory Management Task Force (LMTF). The LMTF is a standing working group chaired by the Office of the Secretary of Defense involving senior laboratory managers from the three military departments. This group has aggressively addressed a variety of laboratory-oriented issues and has obtained major improvements in policy and procedures. It continues to be a model of joint cooperation and action to focus on the welfare of the DOD laboratories.

- Renewed commitment to addressing the imposing challenges to U.S. technological superiority and the addressing of hard issues underlying the vitality of defense science and technology.

These thrusts and associated efforts directly affect the laboratory issues of image, operations, and long-term perspectives. They have resulted in management initiatives to:

- Provide laboratory managers with the responsibility, authority, and flexibility to manage laboratories and technical programs through use of broad guidelines and without overlapping controls.

- o Ensure competency of personnel by:
  - Recognizing clearly that the most valuable resource of the laboratories is the capability, skill, and creativity of their personnel.
  - Providing for personnel stability, challenging work, and meaningful incentives.
  - Providing for equal opportunity for career development, training, promotion, recognition, and reward.
- o Upgrade facilities and equipment by:
  - Removing limitations which constrain modernization of laboratories.
  - Promoting productivity, energy efficiency, and cost avoidance through policies which provide for modern facilities and equipment.
  - Basing replacement policies on practices that befit the business venture nature of research and development activities.
- o Provide effective procedures for procurement and acquisition by:
  - Providing laboratories with the authority and capability to make procuremnts and acquisitions in a timely and efficient manner.

- Ensuring technical acceptability in contractor performance.

o Achieve continuing assessment and accountability by:

- Conducting periodic evaluations to assess the health of the laboratories, the quality and quantity of their contributions, and their performance against the public's legitimate expectations of efficient and effective use of personnel and financial resources--including the vigor of their partnership with industry and the academic community.

G. PERSONNEL - A CENTRAL CONCERN

Over the years there have been numerous high level review groups both internal and external to the DOD, which have examined the state of DOD in-house laboratories. These panels have found that the laboratories are necessary and perform a vital function reasonably well. They do this despite conditions which make such performance extremely difficult. Each panel has recommended actions to mitigate the negative environmental factors identified. There is a consistancy across these recommendations from panel to panel, and from year to year, suggesting that serious problems degrading the laboratories performance remain unchanged despite repeated identification. Representative major review panels since 1980 have included:

o DOD Laboratory Management Task Force - report of management constraints on the Laboratories (1980)

o Defense Science Board Summer Study of the DOD Technology Base (1981)

- Joint Logistic Commanders Study of Engineers (1981)
- Defense Science Board University Responsiveness Study (1982)
- Independent Review of DOD Laboratories (1982)
- Army Science Board Summer Study of Army Military and Civilian Scientists and Engineers (1982)
- DOD Laboratory Management Task Force Study of Scientists and Engineers in DOD Laboratories (1982)
- National Academy of Sciences Report on the Professional Environment in Army Laboratories and its Effect on Scientific and Engineering Performance (1983)
- White House Science Council Federal Laboratory Review Panel (Packard Committee) (1983)
- Report to the President on implementing the recommendations of the White House Science Council Federal Laboratory Review Panel (1984)

Major recommendations for corrective actions may be summarized as:

- Aggressively recruit scientists and engineers (S&Es).
- Adjust S&E pay scale to meet services' needs and market competition.
- Develop a systematic integrated pre-college through postdoctoral fellowship/career development program to

attract, retain, nurture, and develop S&E personnel and skills identified as critical to service needs--include informal training, such as conference attendance.

- Modernize laboratory equipment and facilities--review on regular basis, priorities requirement and implement.

- Remove personnel and high grade ceilings--let mission and program dollars drive personnel levels, holding laboratory directors responsible.

- Increase support personnel to S&E ratio--which will enable S&Es to better perform their critical roles.

- Provide laboratory directors with maximum possible flexibility to manage resources and review results for their respective areas of responsibility.

- Establish a scientist and engineer personnel system which includes flexibility to rapidly employ both permanent and temporary senior specialists.

- Improve links with universities--develop cooperative arrangements, centers of excellence, and significantly increase basic research in the university sector.

One of the major recommendations made by the White House Science Council's Federal Laboratory Review Panel was to create a scientific/technical personnel system that would be independent of the current Civil Service system. Since October 1983 an interagency group under the Federal Coordinating Council for Science, Engineering, and Technology has been working on that recommendation. What is needed is a system which would:

- o Permit agencies to include scientific and technical personnel in the new personnel management systems;

- o Simplify job evaluation and remove covered positions from the position classification requirments of 5 U.S.C., chapter 51;

- o Provide flexibility to develop salary structures which ensure a competitive position in the labor market and which reflect the hiring and pay policies needed to attract, retain, and motivate a highly qualified scientific and technical work force;

- o Base pay increases on performance, not longevity;

- o Allow limited waiver of pay cap for up to five percent of specially qualified scientific and technical personnel;

- o Provide for performance and special awards and remove pay cap for lump-sum awards; and

- o Permit the creation of a Senior Scientific and Technical Personnel Service.

Modern research facilities, equipment, and instrumentation are also required to attract, retain and motivate the best scientists and engineers. Each year, the in-house laboratories compete for the limited funds budgeted within each Service for military construction (MILCON) projects required for laboratory modernization and associated equipment. The competition is keen and many projects and equipments deserve support. During FY86, DOD will assess in-house research facility and instrumentation requirements. These needs will be reflected in future budget requests; an effort paralleling the multi-

year upgrading of university laboratories may be called for. As an example, the DOD laboratories critically need improved access to supercomputer technology; options are being explored.

Another area of serious concern is contracting for technology support. The procedures currently existent are, at best, usually cumbersome and lengthly. As currently configured they have a negative impact on the efficiency and effectiveness of laboratory science and engineering personnel. This situation is particularly critical in the area of evolving science and technology.

H. DOD POSTURE AND RECOMMENDATIONS

The foregoing sections provided a highly condensed summary of representative DOD involvements to address the issue of the maintenance and development of technical skills in the DOD laboratories. This summary clearly demonstrates a heightened awareness on the part of top management, in the Office of the Secretary of Defense and in each of the military departments, of the need to focus on laboratories and their institutional needs. As a result of this intensified managerial attention, numerous improvements have been made and action to achieve others is in progress.

To assist DOD in addressing the effective mission performance of in-house laboratories, we need an alternative personnel management system to improve the quality of scientific and technical personnel. This system would improve our management flexibility and ability to attract, retain, and motivate a qualified scientific and technical workforce.

In summary the DOD must address barriers to good laboratory management, especially in the following areas:

- Personnel - We need a performance-based personnel management system for Scientists and Engineers. It should give supervisors a major role in the position description and classification of people.

- Facilities - We need an aggressive program for 15 years to modernize and update laboratories, facilities and instrumentation.

CHAPTER IV

DOD-INDUSTRY INTERACTIONS

A. INTRODUCTION

This chapter addresses the DOD research and development program performed by U.S. industry. This represents approximately 68 percent of the $31 billion FY 1985 research, development, test, and evaluation program (RDT&E) funded by DOD. Differences between R&D and systems acquisition contracting needs are discussed broadly. Specific DOD initiatives with respect to large corporations (Independent Research and Development-IR&D) and small corporations (Small Business Innovative Research-SBIR) are examined. Simplification of the contracting process for small R&D contracts is recommended; this would require legislative action.

B. IMPORTANCE OF INDUSTRY TO NATIONAL DEFENSE

A strong free enterprise economy and industrial base--here and abroad--are the essential underpinnings of our defense posture. Investment in our technology base and maintenance of our technological strength are critical to the long term security of the U.S. and our allies. Success in achieving the military posture we need is highly dependent on modern technology and its coordinated application.

DOD cannot effectively field this technology without an increasingly efficient industrial base.

C. CONTRACTING ISSUES

DOD contracting for R&D as well as systems acquisition is defined through public law, implemented through the Federal Acquisition Regulations, and further interpreted by Service regulations. Service interests are primarily in systems acquisitions involving large dollar amounts that are subject to considerable Congressional scrutiny. Examples of such systems include the B-1 aircraft, the TRIDENT submarine, and the M-1 tank. These systems acquisitions are characterized by large numbers of items generally integrated by a major contractor with many subcontractors. The contracts are typically competitive, multiyear procurements encompassing provisions for large numbers of items and many spares for subsystem replacement or maintenance.

The DOD Science and Technology program, by contrast, is quite different in content and approach. In the DOD laboratories, scientific and engineering personnel are searching for new innovative ideas and better ways to solve persistent problems either of which may lead to totally new capabilities. Laboratory contracts, on the average, are much smaller (in dollar value) than system contracts and are likely to

be one-of-a-kind demonstrations rather than large numbers of similar items. This contrast suggests that there may be a need for special contracting provisions for the laboratory community.

A review of Air Force data for basic research shows that the average contract or grant is approximately $95,000 per year. A similar review of exploratory development gave an average contract size of approximately $195,000 per year. Although the Army and Navy did not collect data in a similar manner, it can reasonably be assumed that most contracts in the Science and Technology (S&T) program are less than $300,000 per year. Using $300,000 as a point of reference gives about 10,000 procurement actions for the FY 1985 DOD program in research and exploratory development ($3,380 million). This simple calculation gives an idea of the contracting workload generated at the laboratories in a typical year. It also is indicative of the potential benefits of the simplification of contracting procedures.

In recent years, there have been significant changes in procurement law relating to competition and innovation. They have generally lengthened the contracting process. A quick review of these changes yields the following added requirements to the contracting process:

a. Small business subcontracting plans - required in contracts/modifications expected to exceed $500,000 with the potential for subcontracting (small business concerns are exempt).

b. 30 day delay for RFP issuance for proposed acquisitions in excess of $10,000.

c. Requirement to allow at least 30 days for proposal preparation.

d. Approval of the Head of the Contracting Activity on all proposed sole source acquisitions over $500,000 (to be increased to $1,000,000 in April 1985).

e. Lowering of the threshold for certified cost and pricing data from $500,000 to $100,000.

These changes have generally lengthened the contracting process for the technology base.

To fulfill their missions, DOD laboratories must keep abreast of new developments in science and technology. This is an ongoing process, made more challenging as the pace of R&D innovation, both foreign and domestic, accelerates. Activities pursuant to this objective range from the review of industry IR&D programs to soliciting new ideas from universities and industry including small business concerns. The IR&D program and the Small Business Innovative Research program are discussed in Sections D and E of this chapter. The special instrumentation program for universities has already been discussed in Chapter II.

The discussion thus far has developed a perspective for laboratory technology, but leads to some philosophical questions which should be considered, i.e.,

a. Should there be special procedures for small contracts?

b. Should there be special procedures for DOD (and, perhaps, all Federal) laboratories for the purpose of stimulating technology transition and special cooperative efforts?

D. INDEPENDENT RESEARCH AND DEVELOPMENT (IR&D)

IR&D, as defined by DOD, is a contractor-funded R&D program. The R&D efforts are chosen and conducted by the contractor to maintain and improve his technical competence and competitive position in the marketplace. Thus if a company must continually come out with new and updated products to remain competitive, it is advantageous to conduct an IR&D program to develop these new or improved products. Manufacturers of automobiles, minicomputers, word processors, steel, aluminum, plastics, air conditioners, and refrigerators are typical examples of commercial sector companies that would be likely to conduct IR&D programs. In any given year, companies recover IR&D program costs through sales of their products. These products could be end items, such as airplanes, boats, and automobiles, or the results of research performed on R&D contracts. Likewise, companies that develop weapon

systems or subsystems must conduct IR&D programs to remain competitive in the DOD market place.

DOD has the following objectives for the IR&D program:

a. Encourage innovative R&D efforts for DOD systems and equipment which complement and broaden the spectrum of DOD concepts.

b. Develop technical competence in two or more contractors to encourage competitive responses to DOD procurement efforts.

c. Contribute to the economic stability of the private sector by allowing companies sufficient technical latitude to develop a wide variety of products for a broad base of DOD customers.

DOD currently has two special thrusts for the IR&D program: increasing industry-university interactions and emphasis on weapon system support and readiness issues. These thrusts are described below.

a. Industry-University Interactions - The goal is to encourage increased interactions between DOD contractors and universities, both to strengthen the technical

manpower base from which industry draws, and to increase the rate of technology transition from the academic community to industry. Desired interactions are those that strengthen research capabilities of the universities in science and engineering, contribute to development of high quality science and engineering graduates, and promote transition of research results into new applications.

b. Weapon System Support and Readiness - Improvements in support and readiness are major DOD objectives in the weapon system and logistic support technology areas. Technical innovation is essential in order to improve the readiness of our systems. Increased emphasis is required on technology areas which increase mission reliability, reduce dependence on support equipment, spares, and repair facilities, and reduce the need for highly-skilled personnel. Since these objectives are being integrated into DOD programs, it also is important that these objectives be reflected in defense contractor IR&D programs.

DOD manages the IR&D program in accordance with the requirements of Public Law 91-441, Section 203(a). This law authorizes DOD to pay IR&D and bid and proposal (B&P) costs only if the work for which payment is

being made is relevant to the functions or operations of DOD and if specific conditions (discussed below) are met for companies that recover more than $2.0 million in IR&D and B&P costs per year from the DOD. Public Law 96-342, Section 208, raised this threshold to $4.0 million and delegated authority to the DOD to increase this threshold every third year consistent with economic criteria. The next paragraph describes DOD activities which meet the specific conditions of Public Law 91-441, Section 203(a), as amended by Public Law 96-342, Section 208.

a. DOD currently negotiates advance agreements establishing a dollar ceiling on IR&D and B&P costs with all companies which, during their preceding fiscal year, received more than $4.4 million of IR&D and B&P payments from DOD. These ceilings are either negotiated directly with each such company or with those product divisions within a company which contract directly with DOD and which received more than $550,000 of IR&D and B&P payments from DOD. The IR&D ceiling is based on a contractor-submitted technical plan which DOD evaluates prior to or during the fiscal year of the advance agreement. DOD's allocable share of a company's IR&D and B&P costs can be no larger than the dollar value of IR&D and B&P efforts which have a potential relationship to a military operation or function.

b. For companies which during the preceding fiscal year received less than $4.4 million of of IR&D and B&P payments from the DOD, the IR&D and B&P ceilings are set by formula (Federal Acquisition Regulation 31-205.18). While the company does not have to submit a detailed technical plan to DOD for evaluation, it must submit a summary of the individual IR&D projects to the Administrative Contracting Officer responsible for determining the overhead rate for the company. Again, DOD's allocable share of a company's IR&D and B&P costs can be no larger than the dollar value of IR&D and B&P efforts which have a potential relationship to a military operation or function.

The growth of IR&D expenditures by contractors is shown below. Also, the percentage of these IR&D costs allocable to DOD has increased, due primarily to the growth in the DOD budget and the concurrent downturn in commercial sector sales.

IR&D COSTS
(Millions of Dollars)

Fiscal Year	1980	1981	1982	1983
Contractor-Incurred Costs	2373	2746	3654	3930
DOD Share	745	936	1193	1441

In order to focus IR&D Programs to meet DOD requirements, DOD interacts in several ways with contractors on technology base requirements:

a. Requirements information is transmitted to contractors through the technical comments made by individual evaluators during the annual review of contractor-submitted IR&D technical plans. Requirements information also is transmitted during formal and informal IR&D on-site reviews of the individual contractor programs.

b. Contractors discuss future requirements with the technology area focal points identified in the requirements documents issued by each Service. These documents are available to both current and potential contractors through each Service's Information for Industry Offices.

c. Most Service laboratories brief industry representatives annually on future requirements.

The following actions are recommended to improve DOD-contractor interactions on technology base requirements:

a. All DOD and Service R&D organizations should update their requirements documents and lists of technology area focal points on an annual basis.

57-279 O - 87 - 44

b. All DOD and Service R&D organizations should brief industry annually on future technology requirements.

c. All Service R&D organizations should continue to emphasize technical interaction with IR&D programs, including participation on both IR&D technical plan evaluations and on-site reviews. Industry IR&D planning will be influenced as companies gain further insight into DOD requirements. Likewise DOD planning will be influenced by the improved communications and understanding of technology emerging from industry.

E. SMALL BUSINESS INNOVATIVE DEVELOPMENT (SBIR) PROGRAM

On July 22, 1982, the President signed the "Small Business Innovation Development Act of 1982" (P.L. 97-219). This law was designed to give small high technology firms a greater share of Federal research and development contract awards. It became effective on October 1, 1982.

The Act mandated that all Federal agencies establish an SBIR program if their FY 1982 extramural budgets for research and development exceed a threshold figure of $100 million. (There are twelve government agencies meeting this requirement.) Beginning in FY 1983, DOD had to make available the following percentages of its extramural R&D budget for this program:

Fiscal Year	1983	1984	1985	1986	1987	1988
Percentage	0.1	0.3	0.5	1.0	1.25	1.26
Estimated Amount (Millions of dollars)	16.7	44.0	79.0	160.0	204.0	262.0
Actual Award (Millions of dollars)	20.6	44.6	--	--	--	--

Objectives of the DOD SBIR Program include stimulating technological innovation in the private sector, strengthening the role of small business in meeting DOD research and development needs, fostering and encouraging participation by minority and disadvantaged persons in technological innovation, and increasing the commercial application of DOD-supported research or research and development results.

The SBIR Program consists of three distinct phases. Under Phase I, DOD components make awards to small businesses, typically of one-half to one man-year effort over a period generally not to exceed six months, subject to negotiation. Phase I is to determine the scientific or technical merit and feasibility of ideas or concepts submitted in response to SBIR topics. The topics are published annually in a competitive solicitation document to which small businesses respond with proposals.

All DOD topics address specific R&D needs to improve our defense posture. Awards concentrate on that research or research and development that significantly contributes to proving the scientific or

technical feasibility of the proposed effort, the successful completion of which is a prerequisite for further DOD support in Phase II.

Phase II awards are not based on a solicitation but are made to firms on the basis of results from the Phase I effort and on the scientific and technical merit of the Phase II proposal. Special consideration is given to those proposals which identify a follow-on Phase III funding commitment from non-Federal sources.

Phase II awards typically cover 2 to 5 man-years of effort over a period generally not to exceed 24 months, subject to negotiation. The number of Phase II awards depends on the success rate of Phase I contracts and on the availability of funds. Phase II is the principal research or research and development effort, and requires a more comprehensive proposal outlining the effort in detail.

Phase III is expected to involve private-sector investment and support for any necessary development that will bring an innovation to the marketplace. Under Phase III, DOD may award non-SBIR-funded follow-on contracts for products or processes meeting the mission needs of DOD.

The legislation for this act was modeled after the Defense Small Business Advanced Technology (DESAT) Program instituted by DOD in FY 1982. In Phase I of DESAT, 100 contract awards of approximately $50,000 each were made from 1103 proposals received. From the 100 Phase

I awards, 33 Phase II awards worth $4.7 million were made. The DESAT awards are counted against the mandate of the SBIR Act for the fiscal year in which the awards are made. The DESAT program will be phased out with the completion of the current Phase II contracts.

FY 1983 SBIR Program

For the FY 1983 SBIR Phase I contract program, the three Services and the Defense agencies selected more than 300 research and development topics from a description of needs which were included in the DOD SBIR solicitation brochure. This solicitation had a closing date of May 31, 1983. The following is a breakout of the proposals received and those for which Phase I contracts were awarded:

	Number of Topics	Proposals Received	Phase I Awards
Army	182	1121	96
Navy	131	944	67
AF	75	496	100
DARPA	8	128	12
DNA	10	88	8
Totals	406	2777	283

FY 1984 SBIR Program

The solicitation brochure for the FY 1984 DOD SBIR Phase I Contract Program was mailed out on October 17, 1983 (approximately 42,000 copies were distributed) with a closing date of January 12, 1984.

Resulting proposals were evaluated by the scientists and engineers in the Services and Defense agencies who generated the topic descriptions. The announcements of proposals selected for contract negotiations were made by the Secretary of Defense on August 1, 1984. A breakout follows:

	Number of Topics	No. of Proposals Received	No. Selected for Phase I Negotiations
Army	111	761	78
Navy	147	847	99
Air Force	283	1212	164
DARPA	17	107	15
DNA	8	80	12
Totals	566	3007	368

Of the 283 FY 1983 Phase I contract awards, the following Phase II contract awards are anticipated:

Army - 30 to 35

Navy - 37

Air Force - 50

DARPA and DNA - 8

Funding of the two year Phase II contracts will be by yearly increments.

FY 1985 Program

The SBIR solicitation for Phase I proposals for FY 1985 began with the selection of the research and development topics by the Services and Defense agencies. This process was completed in August 1984. The topics were consolidated into a single DOD solicitation brochure and distributed on 1 October 1984. The Army has 111 topics, Navy 138, Air Force 218, DARPA 17, and DNA 7. Potential offerors had until 31 January 1985 to submit proposals. For FY 1985, the Strategic Defense Initiative Organization will have 18 topic descriptions in a supplemental DOD solicitation released on 1 January 1985, with a closing date of 31 March 1985.

The Small Business Administration (SBA) is charged by P.L. 97-219 with maintaining a source file of all small firms wishing to be notified of the availability of SBIR solicitations from all twelve agencies of the government. DOD makes an automatic mailing of its SBIR solicitations to all of the firms on SBA's mailing lists. The FY 1985 solicitation has been mailed to 21,959 small R&D high-tech firms.

F. RECOMMENDATIONS AND FUTURE PLANS

Based on the discussion in Section A, AF laboratories were asked for policy changes that might substantially reduce the contracting workload on contracts less than $300,000 per year. The responses were varied, but there was general agreement that several actions might be taken to reduce the contracting workload. Some actions would require only Service or DOD regulation changes.

Examples of procedural changes cited which would simplify laboratory contracting for small contracts include:

(1) Eliminating cost schedule reports.

(2) Eliminating the Small Business subcontract requirement.

(3) Relaxing of time accounting requirements.

Three recommendations for major changes (requiring FAR or law changes) were received as follows:

1) Set up an SBIR-like, set aside program for universities to which they can respond with simplified proposals. A portion of the technology base would be reserved for this program. This approach would resolve only a portion of the problem, as the university community represents only a part of the science and technology programs. Also the

university community generally competes well in the research program but does not go beyond applied research into development.

2) Revise PL 98-72 and the Competition in Contracting Act, to remove synopsis requirements for small contracts and consider other restrictions which may be eliminated to encourage more participation in laboratory contract programs without increasing paper work.

3) Arrange for a special contract/procurement instrument (in some ways similar to a grant for basic research) for the laboratory community which would allow simplified proposals, contracting procedures, and administration for procurements with obligations of less than $300,000 per year. This would require legislation to allow simplified procedures and a relaxation of data requirements for small contracts. A simple procedure is envisioned that could be applicable to small business, the university community, and those researchers in major industrial laboratories working on new technologies. The proposed instrument might also take the form of a cooperative agreement whereby DOD and the contractor/grantee would share costs, one buying equipment and the other providing workspace and salaries. It would appear that considerable savings in

time and effort could be made by allowing laboratory extramural programs more flexibility in 6.1 and 6.2 procurements with obligations of less than $300,000 per year. Furthermore, it is likely that both government S&E personnel and the proposer community would welcome a dialogue on the subject.

4) Authorize the use of small purchase procedures and forms for small R&D contracts or permit the use of purchase orders.

5) Give consideration to the use of Basic Ordering Agreements with task orders as an acceptable type of contract for certain R&D and R&D service requirements.

In summary, this chapter started with a discussion of laboratory programs in science and technology, and ways in which they differ from systems acquisition programs. Short sections on industry participation in IR&D and SBIR were included to give examples of the breadth of current programs which support the national technology base. The conclusions encompass a possible new approach to simplifying the technical interaction between government laboratories, industry, and universities. As a result of this study, DOD will propose draft legislation which would simplify contracting for small R&D contracts.

CHAPTER V

TECHNOLOGY BASE ACTIVITIES OF OUR ALLIES

A. OBJECTIVES

The United States and its allies are relying on superior technology to meet the threat posed by their adversaries. In sheer quantities of military resources, our adversaries have us outnumbered. We must, therefore, balance this numerical threat in part by relying upon qualitatively superior weapons systems to maintain our collective strength. By equipping our forces with weapons systems that are technologically superior to those of our potential adversaries, we use fewer people and increase the leverage of our defense dollars. To counter the threat in any other manner would require substantial increases in the military budgets of the U.S. and its allies.

So far, we have managed to stay ahead of the Soviets in most deployed technologies, but in some areas our lead is fragile and, in others, we are clearly behind. Several factors contribute to the loss of, or reduction in, our technological lead. One is the length of time required for weapons systems development. The period from beginning of development to actual deployment can be ten to twenty years, and a deployed life of twenty additional years is not unusual. The fruits of this long-term investment are seriously jeopardized if our potential adversaries obtain a system's technology early in its development or

test cycle. In recent years, DOD has proposed substantial increases in its RDT&E budget for the purpose of deploying technology in weapons systems more quickly than we have in the past. The Congress has been very supportive of DOD's efforts in this regard.

The pluralistic makeup of our allies represents a second area of vulnerability. Joint allied use of advanced technology in weapons systems is subject to multilateral negotiations and mutual agreement among partners. As a result, progress in modernizing our forces is sometimes agonizingly slow, and this pace affords the Soviets time to narrow our technological lead.

The changing relationship between civilian and military technologies also makes our lead vulnerable. Thirty years ago, military technology was far ahead of that in the private sector; sophisticated military electronics had no civilian counterpart. Today the situation is very different. We increasingly find that military systems incorporate technology which already is in the marketplace. The microelectronics revolution, for example, placed advanced computers in the hands of the public long before the military equivalents became part of weapons systems. This situation is of great benefit to the public, but makes it much more difficult to protect our technological lead in important technologies which are available commercially.

Finally, and perhaps most importantly, the massive Soviet effort to acquire Western military technology by both overt and covert means threatens our technological lead.

To maintain our technological lead, we must carefully steer a course between two extremes. On the one hand, we must not restrict technology exchange to such an extent that we actually slow the pace of allied technological development. On the other hand, we cannot be cavalier in the face of Soviet success in acquiring important technology. Like many difficult real-world problems, control of unfavorable technology transfer is within the realm of the possible; it requires a pragmatic approach that balances the competing policy considerations and also achieves a favorable benefit-cost ratio.

Our technological lead can be increased or maintained in two ways--by moving the West further ahead and by holding the Soviets back. Recognizing this, the United States has adopted an approach of promoting technology exchange and development with our allies, while at the same time restricting technology transfer to potential adversaries. These activities complement each other; neither can succeed alone.

With regard to export control, the United States has undertaken initiatives designed to restrict the flow of militarily critical technology to our potential adversaries. These initiatives constitute a realistic course of action. They recognize that it is impossible to

prevent all undesirable technology transfer. Some transfer occurs and will continue to occur illegally. An open society, which is absolutely essential to our continued scientific and technological progress, creates some targets of opportunity for the Soviets that we can never fully protect.

The objective of export controls, then, is delay, not prevention. High technology is a perishable item and, during its useful life, we want to make the know-how difficult for the Soviets to obtain. If they do succeed, we want to make the effort as costly as possible. Let the Soviets expend their own resources to acquire high technology rather than get it from the United States and its allies at a fraction of what it cost us to research it, develop it, engineer it, manufacture it, and control its quality. We will be better able to maintain our advantage if the Soviet economy has to bear the full economic costs of technological innovations.

It is also important to recognize that the United States, with few exceptions, does not have a monopoly on technology. Therefore, if controls are to be effective, they must be multinational. Otherwise, American industry would find itself, in effect, excluded from marketplaces that are open to its foreign competitors.

Finally, our export control efforts acknowledge that the United States, as a practical matter, cannot police all activity of this

kind. Consequently, the government's limited resources are concentrated on those areas offering the highest potential payoff.

B. CURRENT MECHANISMS FOR EXCHANGE, COOPERATION, AND COLLABORATION

DOD is working closely with U.S. allies to identify technological opportunities which make the best use of our combined resources and achieve the objective of maintaining superior technology for future weapons systems. In addition to informal approaches, there are several formal mechanisms which promote the objective. Among the latter are The Technical Cooperation Program, NATO's Defense Research Group, the Services' basic research offices in London and Tokyo, and, more recently, the technology assessment teams established to explore the transfer of military technology from Japan to the United States.

The Technical Cooperation Program had its origins in a Declaration of Common Purpose made in 1957 by the President of the United States and the Prime Minister of Great Britain. The statement recognized that the concept of national self sufficiency was out of date, that the countries of the free world are interdependent, and that progress and safety could only be found in genuine partnership by combining resources and sharing tasks in many fields. Since then, Canada, Australia, and New Zealand have joined the program. A number of subgroups were established in appropriate fields of defense research and development. Briefly, the purpose of the subgroups is to formulate proposals designed to obtain

maximum cooperation and optimum employment of resources for research and development, and to ensure as complete an interchange of information as possible among the five countries in designated areas of the defense research and development technology base. Among the designated areas are chemical defense, undersea warfare, aeronautics technology, infrared and optical warfare, communications technology, behavioral sciences, and conventional weapons technology.

NATO has established the Defense Research Group. The Group consists of senior national representatives capable of speaking with authority on the application of science and technology to military problems and resulting national research programs. The Group has several objectives: to exchange information on new research and technology which might lead to future equipment; to review the possible military consequences of advances in the fields of science and technology; to identify suitable areas or individual proposals for bilateral or multilateral cooperation in defense research; to implement this research; and to avoid duplication of effort. Technical panels and research study groups have been established in physics and electronics, optics and infrared, defense applications of operations research, defense applications of biomedical research, electronic warfare concepts and technology, long-range research related to air defense, and long-term scientific studies (not technology specific). In addition, a special study group has been established in concealment, camouflage, and deception.

Recently, the NATO efforts have concentrated on emerging technologies in four mission areas: (1) defense against first echelon attack; (2) attack of follow-on forces; (3) counter-air; and (4) C^3I and counter-C^3I. The goal is to make visible and expeditious progress in cooperative efforts to field effective systems that would otherwise not be widely deployed--in other words, to concentrate on the utilization of more proven technologies in deployed systems.

More recently and of more interest to this report, there has been increasing attention to technology emerging from basic and applied research efforts. The increasing interest in being able to identify, at an early stage, the technologies which may be important to future defense systems is fueled as much by economic considerations as by security. Some of the questions which are being addressed are how to identify high-leverage technologies, whether an identification procedure could be used for an investment strategy, and what degree of protection or control should be provided.

The Services maintain research offices in the U.K. and Japan to meet their needs in matters relating to science and technology overseas. The primary responsibility of those offices is to keep informed on scientific and technological developments in Europe, the Middle East, and the Far East. The offices also establish contacts between American and foreign scientists in important technical areas and provide liaison between the U.S. and foreign scientific communities.

During the past two years, DOD has worked with the Japanese to implement the Nakasone Cabinet's January 1983 policy statement allowing the transfer of certain military-related technology to the U.S. DOD hopes to establish a long term program of cooperative efforts and transfer of technology. Our initial efforts have been toward assessing the status of Japanese technology in the area of fiber optics, electro-optics, infrared and millimeter wave components, and sensors. This was accomplished by a team of experts who visited Japan in 1984. The teams' assessment, conclusions, and recommendations are being evaluated in DOD.

C. SUMMARY

In Europe, both the need and the opportunity exist to increase cooperation with our allies. European economic conditions are not as favorable as those in the United States and, as a result, many countries are cutting back on research. European researchers are some of the best trained in the world, usually have excellent equipment, and, in certain areas have unique data gathering capabilities.

The situation with regard to Japan is somewhat different. The Japanese government, business managers, bankers, and researchers select their technological areas based on long term national industrial and economic needs. Although excellent basic research is conducted, the emphasis is definitely on the application of technology. This does not mean, however, that there are no opportunities for increased collaboration.

As described in this report, there are many joint programs, joint developments, joint experiments, and data and information sharing activities with our allies. Where appropriate, the cost of this effort is shared. Since the United States and its allies are relying on superior technology and the leverage it provides, it is essential that we reexamine the resources that the United States is applying to the technology base portion of DOD's RDT&E budget. Otherwise, future weapons systems will not have the leverage of superior technology and the United States would have to increase its defense expenditures in an effort to match adversaries tank for tank, plane for plane, man for man.

CHAPTER VI

CONCLUSIONS

DOD recognizes the importance of the nation's scientific establishment to our future security. This establishment, a combination of our universities, industry, and in-house laboratories, requires continued attention to ensure that it is sustained at a sufficient level, and is of sufficient quality, to maintain our technological lead over potential adversaries.

This report, prepared at the request of the Senate Committee on Armed Services, has addressed the DOD S&T program and has identified areas which need and are receiving special attention:

- Additional funding is needed to pursue defense science and technology programs required to sustain a U.S. technological lead. Two specific actions have been taken. Approximately 9 percent real growth has been requested in the FY 1986 budget. In addition, the Secretary of Defense has issued guidance for real growth in both the Basic Research and Exploratory Development Programs starting in FY87.

- A DOD-University Research Initiative to help revitalize university science infrastructure as a step toward maintaining the S&T base required for national security has been included in the FY86 budget. Particular attention will be given to potentially high payoff projects in emerging technologies, research instrumentation, graduate fellowships, and research assistantships.

In addition:

- Improvements in the quality of the scientists and engineers at in-house laboratories as well as universities are being sought. A new personnel management system for scientific and technical personnel in the Federal government is needed to improve management flexibility and the ability to attract, retain, and motivate a high quality scientific and technical workforce.

- Research instrumentation is needed to provide scientists and engineers with the tools required to perform quality work. FY 1986 will be the fourth year of a five year, $150 million program to upgrade instrumentation of universities performing defense-related research. In addition, DOD is assessing university facility needs to

perform defense-related research. The report on this assessment is in preparation and will be provided to the Congress when completed. During 1986, DOD will assess in-house laboratory research instrumentation and facility requirements. These needs will be reflected in future budget requests.

- Efficient interactions in the S&T Program among the in-house laboratories, universities, and industry are needed. DOD currently is reviewing potential changes to internal procedures in order better to accommodate the Federal Acquisition Regulations, PL 98-72, and the Competition in Contracting Act. If necessary, draft legislation will be proposed to facilitate these activities.

- S&T cooperation and collaboration with our allies, which engenders a larger common technology base and enhances mutual understanding of defense technologies is strong and should be strengthened if possible. Bilateral and multilateral agreements for jointly developing and sharing technology are being improved with particular emphasis on agreements with NATO, The Technical Cooperative Program countries, and Japan.

THE DEPARTMENT OF DEFENSE
REPORT ON

SELECTED UNIVERSITY LABORATORY NEEDS IN SUPPORT OF NATIONAL SECURITY

PREPARED FOR THE SUBCOMMITTEE ON
RESEARCH AND DEVELOPMENT OF
THE COMMITTEE ON ARMED SERVICES OF
THE UNITED STATES HOUSE OF REPRESENTATIVES

29 APRIL 1985

TABLE OF CONTENTS

	Page
Chapter I: INTRODUCTION	1
A. Rationale	1
B. Definitions	2
C. Research Disciplines and Thrust Areas	2
D. Information Acquisition	3
Chapter II: DOD SUPPORT FOR UNIVERSITY LABORATORIES	5
A. Introduction	5
B. Origins of DOD Support for University Laboratories	6
C. Present DOD Support for University Laboratories	7
C.1 Direct Funding of University Research	7
C.2 Instrumentation Program	11
C.3 University Research Initiative	13
C.4 Coordination Activities	13
Chapter III: PREVIOUS STUDIES	14
Chapter IV: SELECTIVE UNIVERSITY LABORATORY MODERNIZATION	23
A. Introduction	23
B. Disciplines	25
B.1 Chemistry	25
B.2 Electronics	27
B.3 Engineering	28
B.4 Materials	29
B.5 Physics	31
C. Summaries	32
Chapter V: DISCUSSION AND RECOMMENDATIONS	55
A. Discussion	55
B. Recommendations	58
Appendix	59

CHAPTER I

INTRODUCTION

A. RATIONALE

The Report of the House Armed Services Committee on the 1984 Department of Defense Authorization Act contained the following request: "Many of the university laboratories in which Department of Defense research programs are conducted are obsolete and in need of major modernization or replacement. The committee believes a study should be undertaken on the need to modernize university laboratories in the physical sciences, earth and ocean sciences, atmospheric sciences, engineering, computer sciences and other fields essential to our long-term national security. The survey should (1) document the laboratory needs of universities presently engaged in Department of Defense competitive research programs, (2) assess priorities by academic field, (3) provide estimates of costs to meet these needs, (4) provide specific recommendations appropriate to the Department of Defense and others designed to address the need, (5) state the consequences to our long-term national security."
This report is a response to that request.

The science and technology (S&T) base has, as its cornerstone, basic research which, in the U.S., tends to be concentrated at universities. Approximately two-thirds of basic research in science and engineering (S&E) is carried out in academia. There is a concomitant integration of basic research with graduate education. The nation reaps a double benefit from this model in that it concurrently generates both research results and future researchers. It is for this reason that the state of U. S. university laboratory facilities is so important to the nation's long-range economic and military competitiveness.

The evolution of science and technology tends to create a requirement for more sophisticated research facilities. Failure to keep pace with facilities' needs has a negative impact on researchers' creativity. This in turn limits the scope of scientific endeavor in the experimental disciplines. The consequences may include delays in the realization of new discoveries and a trend for faculty and graduate students to opt for theoretical studies rather than engage in experimental research with inadequate facilities. A further consequence is the difficulty of recruiting and retaining the most productive faculty in experimental disciplines.

The foregoing points work against university researchers undertaking experimental investigations. When researchers do so in spite of inadequate facilities, results of their endeavors can be compromised in a variety of ways. These include:

- Inadequate environmental control resulting in decreased quality of data
- Excessive down-time resulting in diminished productivity

- o Outmoded equipment leading to imprecision in acquired data
- o Crowded laboratory space resulting in diminished access to equipment for data gathering and maintenance purposes
- o Contrived experimental set-ups representing safety hazards

B. DEFINITIONS

The following definitions will be used throughout this report:

Laboratory Needs-Facilities and equipment which collectively constitute vehicles for the generation of experimental data and other information. It denotes more than a stand-alone instrument (e.g., spectrometer, tensile tester, etc.) that can be operated in general laboratory space typically found on a university campus, but excludes general purpose laboratory buildings. Examples include wind tunnels, high voltage accelerator labs, clean rooms, wave tanks, etc., especially those housed within existing older buildings. It may also include specially designed structures required to house laboratory instrumentation and experimental facilities.

Facilities-Laboratory structural environment including hardware required to maintain special conditions in laboratory space.

Equipment-Instrumentation and devices directly supportive of data acquisition and analysis.

C. RESEARCH DISCIPLINES AND THRUST AREAS

Selected research laboratory needs among universities active in Department of Defense (DOD) competitive research programs are addressed in this report for the following five disciplines and constituent thrust areas:

CHEMISTRY
- Laser Chemistry
- Polymeric Materials

ELECTRONICS
- Microelectronic Fabrication and Reliability
- System Robustness and Survivability

ENGINEERING
- Combustion
- Composite Structures
- Energetic Materials
- Fluid Mechanics and Acoustics
- Manufacturing, Design, and Reliability
- Soil Mechanics

MATERIALS
- Optical and Magnetic Materials
- Silicon and Compound Semiconductor Growth
- Structural Ceramics
- Structural Composites

PHYSICS
- Astrophysics
- Coherent Radiation Sources
- Directed Energy Devices
- Optical Communications and Spectroscopy

The foregoing disciplines do not represent the breadth of DOD research. In particular, biological and biomedical sciences are not included in anticipation of a comprehensive survey of laboratory needs by the National Institutes of Health. Computer resources not dedicated to experimental research facilities are also excluded on the basis that they are the object of considerable study and/or aggressive enhancement programs by the National Science Foundation and the Department of Energy.

D. INFORMATION ACQUISITION

Requisite information was initially assembled by research administrators in the three Service research offices (OXRs): the Office of Naval Research (ONR), Army Research Office (ARO), and the Air Force Office of Scientific Research (AFOSR) and in the Defense Advanced Research Projects Agency (DARPA). In particular, Division Directors in each organization representing the foregoing five research disciplines supplied data related to the sufficiency of research laboratory facilities. This information was analyzed for the purpose of developing laboratory needs representative of defense research priorities. Results are presented in Chapter IV in the form of prioritized laboratory needs (where they exist), estimated costs of desired enhancements, and assessments of the scientific/technological and national security implications of any laboratory needs identified.

Within the framework of the foregoing information acquisition plan, each of the three OXRs identified key R&D performers for the various research disciplines. These performers were then analyzed with reference to the indicated questions. Criteria used in determining the performers to be interrogated and/or analyzed for inclusion in the report involved level of basic (6.1) competitive research funding, evaluations by OXR research administrators, and, as appropriate, independent evaluations of graduate programs corresponding to the various disciplines. In many cases, the stated costs represent partial funding reflecting the tendency of universities to seek multiple sponsors for major laboratory improvements. While the method of data collection does not embody the statistical integrity of a rigorously implemented survey instrument, it is nonetheless thought to be suggestive of the dimensions of university laboratory needs of greatest importance to DOD. Further, the study differs from previous ones in that the cited laboratory needs reflect, in part, the judgment of research sponsors (DOD scientific officers) rather than exclusively the perceptions of research performers.

The primary DOD research performers encompassed by this report are, of course, only a subset of the total university R&D community. The extent to which their modernization and new facilities needs may be extrapolated to all universities performing research for DOD, or to the entire population of approximately 300 research universities in the U.S., is an open issue. Such extrapolations beg the question, however, as to appropriate means for assessing laboratory sufficiency from the DOD perspective. This is a complex question that is under constant scrutiny for each discipline and its constituent research areas. More generally, it is an issue which demands continued vigilance at the national level. Sustained deficiencies in any discipline/thrust area will inevitably cause the corresponding sector of the U.S. science and technology base to erode, thus blunting our competitive position in the national security and world economic arenas.

CHAPTER II
DOD SUPPORT FOR UNIVERSITY LABORATORIES

A. INTRODUCTION

This chapter deals with the role that universities play in sustaining and strengthening the U.S. science and technology base (Section A), the origins of DOD support of university laboratories in that role (Section B), DOD programs that support university science laboratories (Section C.1), and further steps that DOD has taken to upgrade these facilities (Section C.2). A new university research initiative for FY 86 (Section C.3) and coordination activities relevant to the upgrading of university research facilities are described (Section C.4).

Given the importance of university science laboratories to DOD, it is also true that maintaining adequate university research facilities is a national priority that has important economic as well as military significance. Thus, DOD should not and cannot solve the problem alone. Solutions must encompass all relevant government agencies, private industry, and, of course, the universities themselves. This chapter focuses, however, on the relationship between DOD and the university community.

American universities play an indispensable role in maintaining and strengthening the nation's science and technology base. Not only are universities the source of future scientists and engineers, but the research contributions of academia to society are vast as well. Since World War II, universities have performed most of the basic research that has produced the technological innovations on which much of our economy and national defense are based today. Universities contribute nearly three-quarters of the scholarly papers published in the most noted science and technology journals. In addition to generating the insight and knowledge upon which future technological innovation is based, university research provides the environment for the development of future scientists and engineers. The result is enrichment of the professional experience of faculty and graduate students involved in training our nation's technical manpower. Thus, support of university research produces multiple benefits of enormous value to society as a whole.

This report addresses selected needs of university laboratories involved in DOD sponsored research. As much as $2 billion has been estimated as the total sum needed to replace obsolete university research instrumentation. Laboratory facilities, including the instrumentation required to conduct research aimed at modernizing and expanding the U.S. technology base, are becoming increasingly expensive. Establishing and maintaining such facilities are very costly, especially those requiring advanced supercomputers, large particle accelerators, various types of analytical instrumentation, imaging devices, and automated design and manufacturing hardware. Nonetheless, such equipment is crucial for the conduct of research in important areas of science and engineering, and for educating students. DOD support for university research equipment is described in the following sections.

B. ORIGINS OF DOD SUPPORT FOR UNIVERSITY LABORATORIES

The DOD has recognized that technological superiority is essential to military superiority, and it has played an important role in maintaining the strength of the U.S. science and technology base. Since DOD was among the first federal agencies to recognize the essential role that the academic community plays in the maintenance of U.S. technological leadership, it has maintained a strong relationship with U.S. universities since before World War II.

Very little involvement of universities with military technology occurred during World War I, despite the existence of in-house Service laboratories since the 1890s and the earlier creation of the National Academy of Sciences, which was established as a war measure by President Lincoln in 1863. The sudden expansion of experimental and laboratory operations that characterized the outbreak of World War II greatly overburdened the Service laboratories. Many civilian scientists and engineers were added to the staffs of Aberdeen Proving Grounds, the Naval Research Laboratory, the Naval Ordinance Laboratory, Taylor Model Basin, Wright Field (Army Air Force), and Fort Monmouth (Signal Corps). Contracting funds were also greatly increased in the effort to catch up to an enemy that had scientific groups investigating improved weaponry since the early 1920s.

The Office of Scientific Research and Development (OSRD) was created, reporting directly to President Roosevelt, and receiving funds by direct appropriation from the Congress. These funds were placed in private and governmental laboratories. The National Research Council of the National Academy of Sciences had been created during World War I and was, by the time of World War II, well known to the military Services, which expanded their use of it. These arrangements formed a close coupling of the organized bodies of scientists and military leaders having a common appreciation of the importance of science and engineering to modern warfare. Major wartime expansion of facilities occurred at several universities. The major contributors included MIT, Harvard, Columbia, the University of Chicago, the University of California, the Johns Hopkins University, and the California Institute of Technology. Radar, acoustics, operations research, navigation, and atomic weapons were just a few of the areas in which notable contributions were made.

Emerging from the wartime era were two lasting methodologies for defense investment in university laboratory facilities. First, the institute concept became well established, wherein non-profit university affiliated laboratories conduct applied research, primarily under DOD support. Products of this era which make major contributions today are Lincoln Laboratories (MIT), the Johns Hopkins University Applied Physics Laboratory, the Applied Physics Laboratory of the University of Washington, the Applied Research Laboratories of the University of Texas, the Applied Research Laboratory of Pennsylvania State University, and the Marine Physical Laboratory, Scripps Institute of Oceanography, University of California, San Diego. Second, the National Security Act of 1947, and the amendment of 1948 which established the three military Departments and the Office of the Secretary of Defense, provided the framework that operates today for support of research at universities through the Army Research Office, the Office of Naval Research, the Air Force Office of

Scientific Research, and the Defense Advanced Research Projects Agency. This partnership has been substantial over the years; seventeen institutions of higher education are among the 595 contractors that received awards of 10 million dollars or more from DOD in FY 83.

C. PRESENT DOD SUPPORT FOR UNIVERSITY LABORATORIES

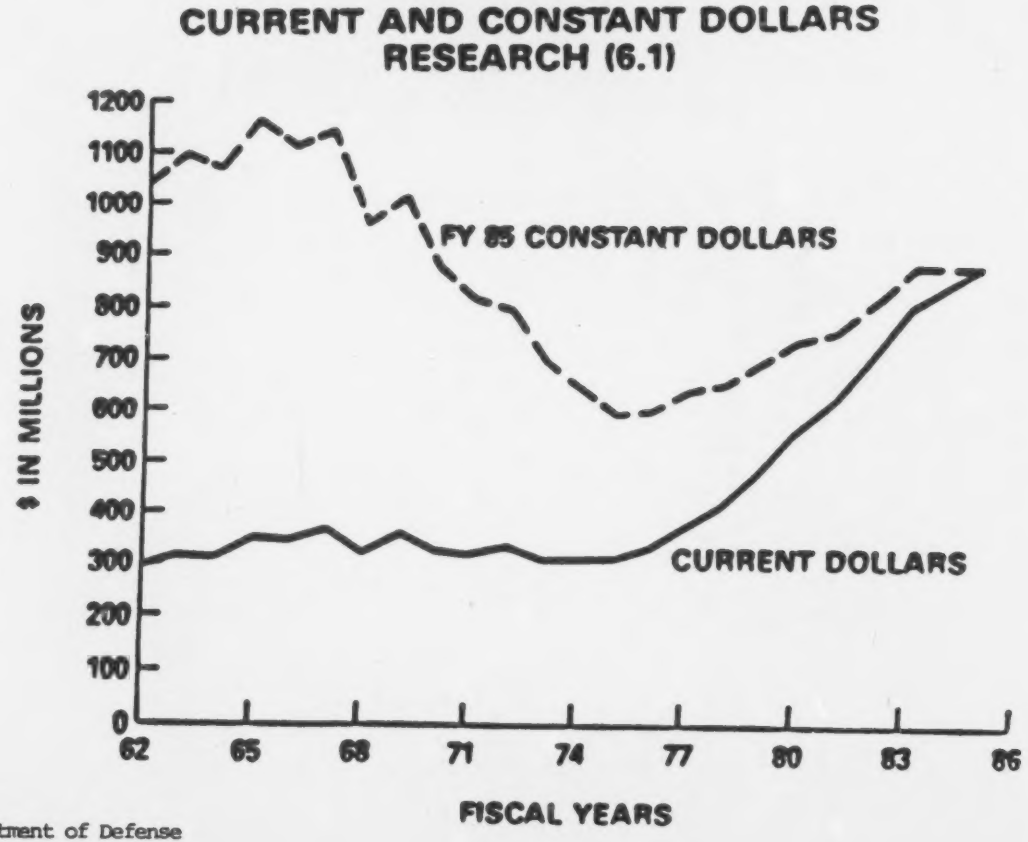
C.1 DIRECT FUNDING OF UNIVERSITY RESEARCH

U.S. universities are a major factor in current DOD activities affecting the U.S. technology base. Approximately half of all DOD basic research (6.1) funds are expended at universities ($405 million in contract dollars with research budgets totaling $840 million in FY 84), plus a smaller amount of applied research (6.2) funds (approximately $115 million in FY 84). During the past decade, DOD has made a major effort to reverse the effects of the relative neglect of university research that occurred during the Vietnam war. Figure II-1 shows the evolution of DOD funding for basic research (6.1) since 1962. The corresponding funding history for "exploratory development" (6.2), some of which equates to applied research, is shown in Figure II-2.

These figures show that funding in current dollars for both components of the technology base grew significantly during the late 1970s and early 1980s; nevertheless, neither has returned to 1965 levels of support in constant dollars. In fact, in real terms, the level of funding for exploratory development has been virtually stable for over a decade. In a memorandum to the Services dated August 9, 1984, Secretary Weinberger noted this situation and indicated that the Defense Guidance for the FY 1987-91 POM would request 8 percent annual real growth in both components of the technology base. DOD still takes that position.

University research has been a major component of the growth in DOD technology base activities during the past decade. Table II-1 shows DOD Basic Research (6.1) funds spent (or projected to be spent) at universities by the Army, Navy, Air Force, and the Defense Advanced Research Projects Agency (DARPA) for the years FY 74-86. During the period FY 75 to FY 84, DOD spending for 6.1 Basic Research at universities grew at a real annual rate of 9 percent--far higher than the annual growth of DOD Research (6.1) funds as a whole.

Table II-1 shows only the DOD Basic Research (6.1) funds going to universities. It includes only contracts exceeding $25,000, and does not reflect research grants. Thus total university funding is somewhat higher than indicated. A similar break-out of the university component of DOD Exploratory Development (6.2) funds is not available. To provide a basis for comparing 6.1 and 6.2 expenditures, in FY 83 a total of $102.3 million in DOD Exploratory Development (6.2) contracts went to universities while $360 million was provided for Research (6.1) contracts. An additional $50 million was awarded to universities in the form of 6.1 research grants. DOD funding for universities is not limited to Research and Exploratory Development. For example, DOD RDT&E (6.1 through 6.6) contracts over $25,000 going to educational institutions in FY 83 totaled $1113.6 million. Most of the $600 million in the higher categories (6.3, 6.4, 6.5, and 6.6) was for R&D in university affiliated off-campus laboratories and Federally Funded Research and Development Centers (FFRDCs), or for vocational and technical training, and tuition fees.

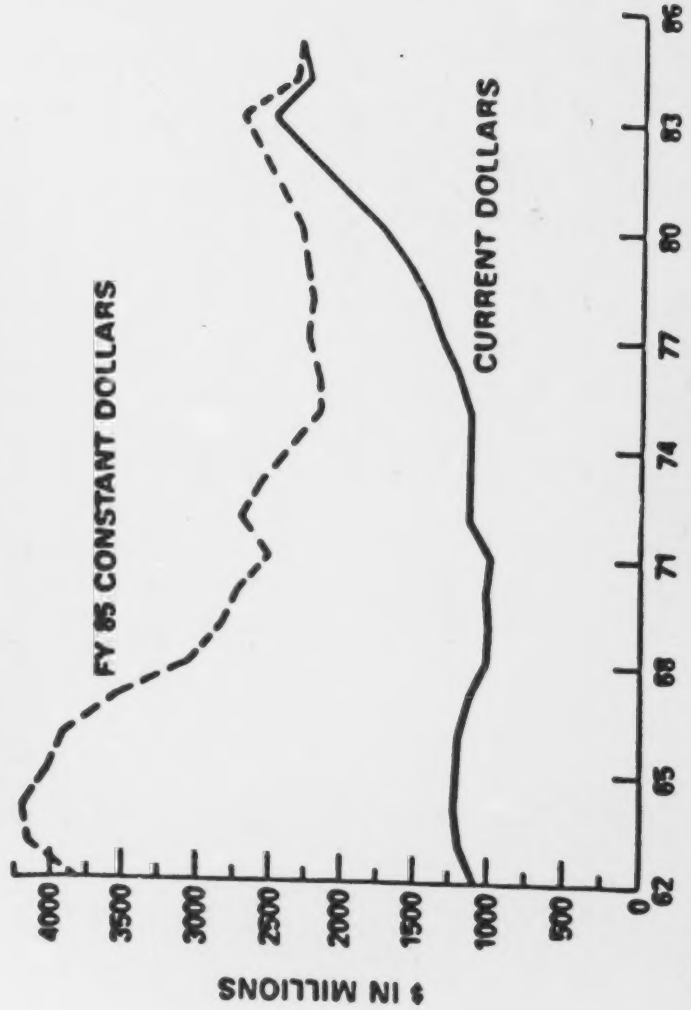


SOURCE: Department of Defense

FIGURE II-1

FIGURE II-2

DOD SCIENCE AND TECHNOLOGY FUNDING TRENDS



SOURCE: Department of Defense

57-279 O - 87 - 45

DEPARTMENT OF DEFENSE FUNDING FOR UNIVERSITY BASIC (6.1) CONTRACT RESEARCH, FISCAL YEARS 1974-85+

(In millions of dollars)

Service	FY 74 Current	FY 74 Real	FY 75 Current	FY 75 Real	FY 76 Current	FY 76 Real	FY 77 Current	FY 77 Real	FY 78 Current	FY 78 Real	FY 79 Current	FY 79 Real	FY 80 Current	FY 80 Real
ARMY	13.7	27.9	13.4	25.0	19.0	33.7	23.7	39.6	28.1	43.8	32.0	45.9	38.1	50.[illegible]
AIR FORCE	23.2	47.3	22.9	42.6	28.2	50.0	41.0	68.6	49.5	77.1	46.4	66.6	55.3	72.[illegible]
NAVY	45.5	92.7	47.0	89.2	64.2	113.8	62.7	104.8	70.8	110.3	86.4	124.0	109.2	131.[illegible]
DARPA	21.9	44.6	19.4	36.1	19.1	33.9	18.7	31.3	17.9	27.9	21.0	30.1	19.8	24.[illegible]
TOTAL	104.3	212.4	103.6	192.9	130.5	231.4	146.1	244.3	166.3	259.0	185.8	266.6	213.4	279.1

Service	FY 81 Current	FY 81 Real	FY 82 Current	FY 82 Real	FY 83 Current	FY 83 Real	FY 84 Current	FY 84 Real	FY 85* Current	FY 85* Real**	FY 86* Current	FY 86* Real**
ARMY	46.5	55.9	56.1	63.5	71.4	77.7	80.6	84.6	83.8	83.8	87.9	83.8
AIR FORCE	63.4	76.2	71.5	81.0	90.3	98.3	112.1	117.6	119.1	119.1	135.0	129.7
NAVY	119.0	138.2	142.3	161.2	152.2	165.6	158.1	165.9	176.1	176.1	198.8	189.5
DARPA	27.3	37.8	39.4	44.6	46.4	50.5	53.9	56.6	42.7	42.7	43.4	41.4
TOTAL	252.2	303.1	309.3	350.3	360.3	392.1	404.7	424.7	421.7+	421.7	459.1	437.7

* Projections

** Forecast for inflation is based on CBO projection

SOURCE: Army Deputy Chief of Staff Research Development and Acquisition, Office of Naval Research, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, (Constant 1985 Dollars Calculated using GNP Implicit Price Deflator)

+Restricted to awards exceeding $25,000; grants are not included

DOD sponsors research and development at universities to ensure the progress in fundamental knowledge that is necessary, in the long run, to maintain U.S. technological superiority. The resulting university research programs also serve to benefit universities in a variety of ways. By providing opportunities to perform basic research at the forefront of science and engineering, research programs at universities help to create an environment that can attract and retain faculty and students. Past studies suggest that, on average, $1 million of funding for research provides full or partial financial support for 10-15 graduate students. Using this measure, DOD provided financial assistance for over 4000 graduate students through its university research programs in FY 84. In addition, as will be noted below, DOD-related research programs also have significant effects on laboratory instrumentation.

C.2 INSTRUMENTATION PROGRAM

Instrumentation is essential to modern research. Modern instruments with qualitatively superior capabilities for analysis and measurement often open new fields of scientific inquiry. In some scientific areas, access to the most advanced scientific instrumentation determines in large measure the extent to which scientists can work at the cutting edge of their field.

The Department of Defense, in concert with the scientific and university community, state and other federal agencies, and the Congress, perceived that the condition of research instrumentation in U.S. universities declined significantly during the 1970s. The Association of American Universities (AAU), in a report to the National Science Foundation (NSF) in June 1980 (see Chapter III), concluded that the equipment being used in the top ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories, an additional factor in the attraction of potential faculty to industry.

The instrumentation problem has been growing for more than a decade. It reflects both economic factors and funding patterns:

- The cost of equipment has risen much faster than inflation.
- The system of one to three year contracts in the $50,000 to $100,000 per year range with individual investigators is not conducive to obtaining equipment that costs more than $50,000.
- Rapid technological advances are rendering research equipment obsolete at an ever increasing rate.

In response to the foregoing situation, DOD has encouraged researchers to include more of their equipment needs in proposals and emphasized that DOD does not set arbitrary limits on the amount of money that may be requested for instrumentation. This approach has been helpful for equipment needs in the $50,000 range or less. However, new money was clearly needed for some of the more expensive items required to modernize university laboratories. These funds were provided in FY 83 through the DOD-University Research Instrumentation Program (URIP), which received Congressional approbation.

URIP provides $150 million over five years for university research equipment. Each of the three Services is programmed to spend $10 million per year. So far, $90 million has been spent on 652 awards going to 152 institutions in 47 states and Washington, D.C., Guam, and Puerto Rico. While URIP is having a major impact on the equipment needs of researchers doing work of interest to DOD, it cannot solve the whole university instrumentation problem. In the first year of URIP, DOD received 2,500 proposals representing requests for $646 million worth of equipment. While some of these requests were for equipment to support research in areas not usually funded by DOD, this response is a significant and impressive measure of the needs of the universities.

URIP is the most visible, but not the sole, DOD response to the university instrumentation problem. As noted previously, each of the Services and DARPA have encouraged current and prospective contractors to make their equipment needs known, in order that many of the less expensive items could be purchased as an integral part of research program funding:

- Approximately 10 percent of Army, Navy, and Air Force research contract funding is applied to equipment purchases, most of it well under $50,000. Grants under the URIP program provide an additional comparable dollar amount for equipment costing more than $50,000.

- The portion of the Army Research Office (ARO) contract program devoted to instrument purchases has increased steadily over the past decade; in FY 85, such purchases will represent about $6 million of the ARO contract research program.

- University-related equipment purchases associated with the Contract Research Program of the Office of Naval Research (ONR) increased from $11.2 million in 1979 to $16.6 million in 1984.

- Between 1975 and 1985, vested equipment funding by the Air Force Office of Scientific Research (AFOSR), during the usual course of its sponsored research program, increased from $2 million to $8 million.

- Although DARPA does not participate in the URIP program, 10 to 20 percent of its university program funds have been utilized for equipment. In 1981, DARPA began a modernization program focused on obsolete equipment and the need for greater computational power. From 1981 to 1984, equipment purchases by universities using DARPA funds increased from $6.7 million to $16.8 million.

In certain cases where the equipment for major research efforts has been especially costly, provisions have been made for extraordinary purchases. Examples include the purchase of large main frame computers, semiconductor processing lines, molecular beam epitaxy and analysis chambers, and ARPANET computational and communication facilities by DARPA, and an ongoing ONR program to refurbish selected research vessels.

In FY 84, in addition to the $30 million per year of special URIP purchases, the three Services and DARPA purchased over $45 million worth of research instruments and equipment for universities in connection with their research contracting activities.

C.3 UNIVERSITY RESEARCH INITIATIVE

In FY 86, DOD plans to establish new research program elements that will be focused exclusively on the DOD/university relationship. Total proposed funding for the new program elements is $25 million in FY 86 and $50 million in FY 87. Significant additional growth is expected after FY 87. Each of the Services and DARPA will implement programs within these program elements to meet the priorities of their own relationships with the academic community. Although the specific proportions will vary from Service to Service, graduate fellowships, support for young investigators, purchase of research instrumentation, support of special research programs, and programs to improve the interactions between DOD laboratory and university researchers, will be part of the total DOD package.

C.4 COORDINATION ACTIVITIES

DOD has long recognized that the academic community is an invaluable source of expert advice. The Department draws on science and engineering faculty as individual consultants and as members of DOD advisory committees. To insure more effective communication with the academic community, DOD established the DOD/University Forum in December 1983. During its first year, the Forum has provided a mechanism for dialogue between DOD and the academic community on policy and other issues of mutual interest. One significant outcome of its activities during the past year was the establishment of a new DOD policy on the transfer of scientific information. It establishes an appropriate balance between the conflicting imperatives of national security and open scientific communications. The Forum Working Group on Science and Engineering Education addressed many issues, including that of research instrumentation.

CHAPTER III

PREVIOUS STUDIES

More than a dozen studies of university laboratory facilities have been prepared since the late 1960s. For a comprehensive listing and summary of such studies prepared by Linda S. Wilson of the University of Illinois at Urbana-Champaign, see the Appendix. Many of these studies have concluded that a problem exists with respect to inadequate and deteriorating university laboratory research facilities. Some of the studies are qualitative and generally recommend programs for the support of facilities renewal. Others are quantitative and are based on surveys of the conditions of facilities, with projections of the amount and cost of construction and renovation required to meet future needs. The basic conclusion drawn is that renewal and replacement of facilities are an important element in assuring a national technology base. Some of the more relevant studies for the purposes of this report are discussed below. An analysis of some of their findings in comparison to the present study is given in Chapter V.

-- A report to the National Science Foundation (NSF) by the Association of American Universities (AAU) in June, 1980, was devoted to "The Scientific Instrumentation Needs of Research Universities." Numerical data for the study were gathered from 14 universities and four commercial laboratories. The report found that the median age of university equipment was twice that of the commercial laboratories' instrumentation. Concluding that "the quality of research instrumentation in major university laboratories" has seriously eroded, the AAU report recommended that:

> "Federal policy for the support of research instrumentation should provide for a basic three-part funding strategy:
>
> - o Strengthen instrumentation funding in the project system.
> - o Expand special instrumentation programs.
> - o Create in the National Science Foundation a new, supplemental formula grant program to provide needed flexibility to meet diverse institutional needs."

-- A 1981 study prepared for the Committee on Science and Research of the AAU, entitled "The Nation's Deteriorating University Research Facilities," was based on a survey of recent expenditures and projected needs of fifteen major U.S. universities in six disciplines. The principal findings of the study were:

- o A substantial backlog of research facilities and equipment needs was accumulating.
- o During the 1978-81 period, for the six fields surveyed, the fifteen universities spent $400 million for facilities and major equipment. In the next three years (1982-84),

these universities expected to spend almost twice as much ($765 million), just to produce the necessary research facilities and special research equipment for current faculty only.

- o New construction to replace outmoded facilities accounted for almost 60 percent of total projected funding requirements across all fields.

- o In addition, substantial needs for major research equipment were identified in all six fields.

Table III-1 shows the expenditures and projected needs for those disciplines included in the present report. Projected needs for both facilities and equipment were far larger (by factors ranging from three to almost ten) than actual expenditures for an equivalent period immediately preceding the report. The extent to which these differences represented realistic assessments of the pent-up facilities demand, and/or an effort on the part of survey respondents to "make a statement," is open to question.

Among the recommendations of the AAU study was:

- o Provided that a review by key government agencies corroborated the assessment of the survey, the "Department of Defense, Department of Energy, the National Aeronautics and Space Administration, the Department of Health and Human Services, and the Department of Agriculture should establish research instrumentation and facilities rehabilitation programs targeted on the fields of science and engineering of primary significance to their missions."

-- In 1982, Flad & Associates, a Wisconsin architectural and planning firm, published their "Capital Spending Study of Research and Development Laboratories." Since the study focused exclusively on the spending plans of private industrial firms, it provides a useful basis for comparison with the plans of universities dealt with in the AAU studies described above.

The Flad study was based on a survey of some 5800 directors of industrial research laboratories. About twelve percent of them responded with detailed, confidential estimates of planned spending for plant and equipment in the ensuing three years (1983-85). The firms surveyed were considered more representative of large research laboratories (25-100 staff) than smaller laboratories (less than 25).

Among the major findings of the Flad study were:

- o Estimated spending on research and development plant for 1983-85 by responding firms was $1.4 billion.

- o Estimated spending on research and development equipment for 1983-85 was $1.2 billion.

- o Nearly 40 percent of the laboratories of responding firms were built less than ten years before the survey; of these, 50 percent had undergone additions or renovations subsequent to initial construction.

Table III-1

Actual and Projected Expenditures for Research Facilities
(new construction/renovation) and Special Research Equipment
for 15 Major Research Universities
(thousands of dollars)

	FACILITIES			SPECIAL RESEARCH EQUIPMENT		
FIELD	1978-80	1981	PROJECTED NEEDS 1982-84	1978-80	1981	PROJECTED NEEDS 1982-84
Chemical Sciences	13,835	14,089	115,022	6,701	4,767	14,688
Engineering	19,539	18,476	183,106	16,101	10,957	33,222
Physics	11,700	5,818	74,725	4,603	1,092	22,590

Source: "The Nation's Deteriorating University Research Facilities",
Association of American Universities, 1981

For the purposes of this report, the Flad study has some interesting implications. If the study's findings are extrapolated onto the entire sample, total national private industry projected capital spending for research and development would be about $20 billion for 1983-85 (about $11 billion for plant and about $9.2 billion for equipment). This compares with estimates of $1 billion for total average annual planned investments in university science and education facilities. For industrial laboratories whose annual research and development budgets were in the range of 1 to 15 million dollars (45 percent of the responding firms), the expenditure planned for was about 13 percent of their annual operating budget each year for the three years beginning in 1983. The ratio of planned expenditures for equipment and plant by private industry was about the same (unity) as that shown for universities in Chapter IV below.

-- The NSF published a study of "Academic Research Equipment in the Physical and Computer Sciences and Engineering" in December 1984. This study surveyed 43 universities; respondents exhibited serious concern about the adequacy of their current stock of research equipment. Among the findings of the study were:

- o About half of the department heads in physical and computer sciences and engineering characterized research instrumentation available to untenured and tenured faculty as "insufficient."
- o 90 percent of the department heads surveyed reported that, as a result of lack of needed equipment, their research personnel could not conduct critical experiments in important subject areas.
- o The top priority need was to upgrade and expand research equipment in the $10,000 to $1,000,000 range.
- o The estimated original purchase cost of the entire 1982 stock of all $10,000 to $1,000,000 academic research equipment that had been accumulated in the fields surveyed was about $1 billion.
- o Only 16 percent of those systems were classified as state-of-the-art. Of the equipment that was not in the state-of-the-art category, over half was in less than excellent condition; about half of such equipment was the most advanced to which researchers had access.

In addition to the studies and data surveyed above, the NSF has released a variety of data that are of special interest for this report. Table III-2 gives seven-year trend data on capital expenditures at all U.S. universities for both research and instructional purposes. Unfortunately, there does not appear to be any systematic way of extracting purely research facility expenditures from these figures. The two research categories cited correspond roughly to the five disciplines addressed in this report.

TABLE III-2

Research and Instructional Capital Expenditures
at Colleges and Universities*

(thousands of dollars)

FIELD	1976	1977	1979	1980	1981	1982	1983
Engineering	81,678	87,718	87,128	89,297	103,329	144,990	134,701
Physical Sciences	73,755	65,216	64,685	77,154	87,813	82,362	87,073
Total:	155,433	152,934	151,813	166,451	191,142	227,352	221,774

Source: National Science Foundation

* 1978 Data not available.

Research equipment expenditures for U.S. colleges and universities are summarized in Table III-3 for 1982 and 1983. The data were obtained from 85 percent of U.S. universities in response to an NSF questionnaire concerning non-capitalized equipment expenditures. Engineering equipment purchases averaged approximately $70 million for the two year period. The category compares roughly to the combined engineering, electronics, and materials categories of this report.

Table III-4 lists 1982 estimated research equipment expenditures for 157 of the largest research universities. These 157 institutions collectively accounted for 95 percent of all nonmedical, non-FFRDC R&D expenditures reported to NSF for FY 1980 by all U.S. colleges and universities. Thus, although the survey represented only a small fraction of the nation's approximately 3,000 post-secondary institutions, it encompassed most institutions with significant capabilities for the kinds of advanced research that require instrumentation in the $10,000+ range. The quoted figures are somewhat higher than those in Table III-3, since they include capitalized equipment, whereas the data of Table III-3 do not. As in Table III-3, the engineering category compares roughly to the combined engineering, electronics, and materials categories of this report.

Acquisition and replacement costs as of 1982 for research equipment in the physical sciences and engineering are given in Table III-5. The total replacement value in 1982 dollars for both fields exceeded $1 billion. It is interesting to note that equipment maintenance in both the physical sciences and engineering represented 5 percent of replacement costs.

TABLE III-3

Annual Expenditures for Research Equipment
at Colleges and Universities
(thousands of dollars)

FIELD	1982	1983
Engineering	65,861	75,171
Aero/Astro	2,284	2,837
Chemical	6,442	6,172
Civil	5,164	6,086
Electrical	18,454	20,685
Mechanical	7,390	10,008
Other	26,127	29,383
Chemistry	33,323	32,826
Physics and Astronomy	38,316	39,916
Totals:	111,373	118,530

Source: National Science Foundation

TABLE III-4

Instrumentation-related expenditures in academic departments and facilities, by field and type of university: National estimates, FY 1982[1]

[Dollars in millions]

Principal field of research in department/facility and type of university	FY 1982 expenditures			
	Total	Purchase of research equipment[2]	Purchase of research-related computer services[3]	Maintenance/ repair of research equipment[4]
Total, selected fields	$375.6	$231.0	$84.7	$60.0
Field of research				
Physical sciences, total	156.6	94.5	33.9	28.2
Chemistry	73.7	39.6	23.3	10.8
Physics and astronomy	83.7	55.2	10.9	17.6
Engineering, total	154.4	90.9	43.9	19.6
Electrical	52.9	36.2	11.5	5.2
Mechanical	23.0	8.7	10.8	3.5
Metallurgical/materials	9.4	7.4	0.8	1.2
Chemical	15.8	7.8	5.7	2.3
Civil	16.4	9.6	5.4	1.4
Other, n.e.c.	36.7	21.3	9.5	5.9

[1] Statistical estimates encompass all research departments and all nondepartmental research facilities in the physical sciences, engineering and computer science at the 157 largest R&D universities in the U.S., except: (a) departments with no research instrument systems costing $10,000 or more and (b) research installations consisting of interrelated components costing over $1 million (large observatories, reactors, accelerators, etc.). Sample size = 353 departments facilities. The columns below do not add up to the indicated totals because computer science and interdisciplinary have been omitted from this abbreviated version of the original table.

[2] Estimates refer to expenditures for nonexpendable, tangible property or software having a useful life of more than two years and an acquisition cost of $500 or more, used wholly or in part for scientific research.

[3] Estimates refer to purchase of computer services at on-campus and off-campus facilities but not to purchase of computer hardware or software.

[4] Estimates encompass expenditures for service contracts, field service, salaries of maintenance/repair personnel, and other direct costs of supplies, equipment and facilities for servicing of research instruments.

Source: "Academic Research Equipment in the Physical and Computer Sciences and Engineering"; National Science Foundation, December, 1984.

TABLE III-5

Number and aggregate cost/value of academic research instrument systems in active research use, by field and type of university: National estimates, 1982.[1]

[Dollars in millions]

Principal field of research use and type of university	Number of systems	Index of aggregate cost/value			
		Purchase cost[2]	Acquisition cost[3]	Replacement value[4]	1982 cost-equivalent[5]
Total, selected fields	17,586	$758.1	$703.2	$1,133.7	$1,162.8
Field of research					
Physical sciences, total	8,424	373.6	353.2	529.3	610.2
Chemistry	4,791	210.4	201.1	295.0	331.7
Physics and astronomy	3,633	163.2	152.1	234.3	278.4
Engineering, total	6,829	259.4	232.4	413.3	374.6
Electrical	1,650	66.4	56.0	92.2	89.0
Mechanical	1,363	50.9	47.8	95.5	66.9
Metallurgical/ materials	998	39.0	36.6	65.2	60.9
Chemical	682	23.3	22.8	28.6	32.3
Civil	397	14.1	13.9	22.4	21.6
Other, n.e.c.	1,739	65.7	55.3	109.0	104.0

[1] Statistical estimates refer to research instrument systems (including all dedicated accessories and components) originally costing $10,000-$1,000,000 in physical science, engineering, and computer science departments and facilities at the 157 largest R&D colleges and universities in the U.S. Estimates limited to systems used for research in 1982. Sample size = 2,582 systems. The columns below do not add up to the indicated total because computer science, materials science, and interdisciplinary have been omitted from this abbreviated version of the original table.

[2] Manufacturer's list price at time of original purchase.

[3] Actual cost to acquire instrument system at this university, including transportation and construction/labor costs.

[4] User estimate of 1982 cost of same or functionally equivalent equipment.

[5] Original purchase cost converted to 1982 dollars using Machinery and Equipment Index of the Bureau of Labor Statistics' Annual Producer Price Index to adjust for inflation.

Source: "Academic Research Equipment in the Physical and Computer Sciences and Engineering"; National Science Foundation, December, 1984.

CHAPTER IV

SELECTIVE UNIVERSITY LABORATORY MODERNIZATION

A. INTRODUCTION

This chapter addresses selected laboratory needs, i.e. facilities and related equipment, for a segment of the research university community representing key performers of DOD research for the disciplines and thrust areas enumerated in Chapter I. These needs, stratified by discipline and priority in Table IV-1, reflect the judgment of university research performers and, in certain cases, of administrators in the Service research offices (OXRs) and the Defense Advanced Research Projects Agency (DARPA). It should be emphasized that the cost figures in Table IV-1 are estimates of university laboratory upgrade and modernization initiatives designed to bring university laboratories closer to sufficiency from the DOD perspective. As previously indicated, they represent in many cases only partial funding of the facilities in question through multiple sponsor arrangements. They are not intended to encompass laboratory needs of the entire university research community. The latter issue has been addressed in the various studies cited in Chapter III. Facilities costs vary among and within disciplines, reflecting special requirements for the various thrust areas. They encompass both floor space requirements and laboratory accessories not falling within the instrumentation category. Thus, not all expenditures classified as "facilities" represent requirements for new or renovated buildings. The stated new floor space requirements are expressed in "gross" (as opposed to "net") square feet at $\$120/ft^2$. Laboratory renovation costs are calculated at $\$90/ft^2$.

The allocation of laboratory needs among the five disciplines required the exercise of judgment as to the appropriate division between (a) the parent, pure science fields of Physics and Chemistry, and (b) the applications-focused areas of Electronics, Engineering, and Materials. Ultimately, such decisions are to an extent arbitrary. Further, there are clearly a great number of ways to stratify facilities and equipment needs in terms of disciplines and thrust areas. The scheme presented in this report is thus only one of many possible approaches.

Priority 1 facilities needs for the five subject disciplines, pro-rated over a five-year expenditure period, are $32 million per year. The expenditure level is equivalent to the URIP annual allocation of $30 million. It is also of interest to note that priority 1 equipment requirements are $31 million per year, i.e., almost identical to the annual expenditure rate of the five-year $150 million URIP initiative. Unquestionably, some portion of the $155 million Priority 1 equipment needs cited in this report will be addressed during the final two years ($60 million) of the URIP program.

Table IV-1. Summary of selected laboratory needs of major university performers of defense research.

Discipline	Priority	Building Requirements (gross ft^2)	Cost ($ thousands)* Facilities	Equipment	Total Costs
Chemistry	1	35,000	5,000	14,000	19,000
	2	412,000	44,700	33,400	78,100
Subtotals		447,000	49,700	47,400	97,100
Electronics	1	130,000	49,000	33,000	82,000
	2	25,000	6,000	8,000	14,000
Subtotals		155,000	55,000	41,000	96,000
Engineering	1	296,500	36,200	39,000	75,200
	2	45,300	8,900	18,300	27,200
Subtotals		341,800	45,100	57,300	102,400
Materials	1	220,000	55,000	62,100	117,100
	2	170,000	29,000	36,400	65,400
Subtotals		390,000	84,000	98,500	182,500
Physics	1	80,000	15,800	9,300	25,100
	2	131,000	25,700	163,300**	189,000**
Subtotals		211,000	41,500	172,600**	214,100**
Summary	1	761,500	161,000	157,400	318,400
	2	783,300	114,300	259,400**	373,700**
Totals		1,544,800	275,300	416,800**	692,100**

*Numbers are rounded to the nearest $100 thousand.

**Includes $150 million for astrophysics high angular resolution imager.

B. DISCIPLINES

B.1. Chemistry

Large facilities are playing an increasingly important role in chemical research. It has been an evolutionary process, starting with opportunities provided by large instrumentation and moving to facilities comprised of clusters of large integrated instrumentation/computational facilities in regional spectroscopic facilities.

Ultra high vacuum chambers with sophisticated analytical instrumentation using laser, electron, and ion cluster beams, together with various spectrometers, are mandatory for leading edge research in many areas of chemistry. Lasers have become important analytical tools to study the dynamics of chemical reactions and to photoinduce reactions. These instruments are usually short wavelength visible or ultraviolet tunable lasers that are themselves pushing the limits of laser technology and hence require considerable expertise and expense to operate and maintain. In addition, many research projects are concerned with the chemistry of materials processing, such as integrated circuit fabrication, that demand clean room facilities by their very nature.

In order to remain globally competitive, particularly in areas of chemistry of importance to DOD, it has been recently recognized that traditional chemical research laboratory facilities at universities are in serious need of upgrading and that shared centralized new facilities are necessary due to the high costs of the instrumentation and environmental control required. This evaluation applies to the two topical areas identified by DOD research managers as candidates for facilities upgrading, based on scientific opportunities and on laboratory needs. These priority topics are laser chemistry and polymeric materials.

Lasers have become a valuable tool in many branches of chemistry. Catalytic activity and selectivity can be studied by using laser Raman spectroscopy to determine the vibrational modes and polarization of structures of molecules adsorbed on single crystal surfaces. High powered photo-ionizing lasers can be used in conjunction with ion cyclotron resonance spectroscopy to study the role of metal ions as selective chemical ionization reagents. Laser induced fluorescence of metallic ions and subsequent transfer of energy to neutral ions may yield superior detection limits, compared to well established analytical techniques that employ fluorescence of neutral metal ions in flames. Two step laser photo dissociation of small molecules can be used to elucidate isotope separation and enrichment processes. In this latter process, an intense pulsed infrared laser vibrationally excites molecules containing the chosen atomic isotope and a second ultraviolet laser photodissociates the molecule, allowing the desired atomic isotope to be collected from the photo fragments. These examples indicate the utilitarian richness of lasers in modern chemistry and illustrate that often they are used in combination with other sophisticated analytical equipment. The facilities investment described here would establish fifteen laser chemistry centers

where the operation and maintenance of the lasers would be accomplished by support specialists to serve several research projects. On an even larger scale of centralization, a single free electron laser facility would also be established to provide a very intense and widely tunable source of radiation.

Polymeric materials are found in most military equipment, because of their excellent chemical stability, mechanical properties, and low cost. The majority of the research support for improvements in these materials comes from industry in pursuit of commercial applications, although DOD does support some research specific to stringent military requirements. However, the polymer research of greatest interest to DOD, and for which university facilities upgrades are needed, concerns conducting polymers and polymeric approaches to structural composites, ceramics, and self-reinforcing polymers. It is important to note that independent industrial support of research in these areas is minimal or not aimed at DOD needs.

Conducting polymers that would combine the processability, durability, and light weight of plastics with the electrical conductivity of metal would find a wide range of applications in military systems ranging from solar cells and batteries to integrated circuits and stealth structures. Polyacetylene was the first organic polymer to exhibit electrical conductivity that could range from that of glass to that of metal, depending on the amount of dopants introduced. Doping methods have expanded to include solution doping, ion implantation, and electrochemical doping. Other new polymers have been made conducting, including polypyrrole and polythiophene. Polymer processability and stability are degraded by the doping methods currently used to induce conductivity. Much research is directed at improved doping techniques and on incorporating conducting polymers into nonconducting polymer matrices, as well as fundamental studies to explain the mechanism of electroactivity.

Fiber reinforced composite structural materials are finding many engineering applications, some of which are described under Materials and Engineering. Examples of the Chemistry research topics include organometallic polymer precursors for producing the fibers and self-reinforced or ordered polymers to attain the mechanical properties of fiber-reinforced composites without the need for fiber reinforcement. The most notable of the self-reinforced polymers developed under DOD sponsorship is polybenzothiazole (PBT), which exhibits an extended rigid chain alignment at the ultra-structural level. It offers low-cost processing, by casting and extrusion, instead of the sequence of weaving fibers, stacking of many thin plys, and curing at high temperature required for conventional fiber-reinforced composites.

Other polymeric materials research includes biopolymers, such as the polysaccarides for reduced hydrodynamic drag and non-linear electro-optic polymers for optical signal processing applications. The facilities investment described here would provide the polymer processing and characterization facilities for several focused centers of university research on electrical, optical, magnetic, and structural polymers.

B.2 Electronics

In addition to the traditional subject areas of electronic devices, circuits, and systems, the Electronics research program of DOD encompasses elements of information processing, low energy laser physics, optics, and material growth. For the purposes of this study, the facilities required for the growth of electronic and optical materials are reported under Materials and the low energy lasers, optical circuits, and vacuum tube research facilities are reported under Physics. The information processing research, being closely related to computer science, is not discussed, since, as mentioned in the Introduction, the National Science Foundation (NSF) and the Department of Energy (DOE) have major facilities programs in progress to provide scientific supercomputing access to university researchers. DOD, through the modernization program of the Defense Advanced Research Projects Agency (DARPA), recently made a significant upgrade in university computing facilities for symbolic computing in anticipation of the thrust in strategic computing. The Office of Naval Research is making available to its principal investigators a significant portion of the time of the Naval Research Laboratories' supercomputer at no cost to the existing research contracts.

A strong and clear consensus has emerged from this study indicating that the research managers of the Electronics program within the DOD feel that microcircuit fabrication at dimensions much smaller than those of the Very High Speed Integrated Circuits (VHSIC) program represents the greatest opportunity and greatest research facility need within Electronics. The feature sizes desired are 10 to 100 times smaller than the one-micron regime currently being advanced under VHSIC. It is in this regime that entirely new modes of operation of electronic, optical, and magnetic devices occur, due to the quantum effects produced by the limited number of atoms contained within these small dimensions. These phenomena present the possibility of creating devices whose performance can be greatly superior to that predicted from the bulk characteristics of the material from which they are fabricated. This has already been observed for high speed field effect transistors (FETS), when the device dimensions are reduced below one-tenth micron. It has also been observed that dramatic increases in transmission properties of optical materials occur when very thin layers of material are stacked in a multilayer sequence, offering the possibility of improved photodetectors and lasers.

The fabrication of these novel devices requires very advanced and expensive equipment for the deposition, lithography, and selective removal of the deposited materials. In addition, sensitive analysis of the surfaces and interfaces between dissimilar materials needs to be performed during the fabrication process. This is in contrast to current commercial practice (even for sophisticated microcircuits), where the analysis by electron microscopes and spectrometers is accomplished after the circuits are removed from the fabrication apparatus and before they are inserted into the next apparatus in the fabrication sequence. This requirement for in-situ analysis has greatly increased the minimum cost of doing research on device fabrication.

The facilities in which this instrumentation is housed require extreme control over air purity, to avoid dust particle disruption of the fabrication, and extreme control over vibration, to avoid misalignment of

the successive patterns employed in the fabrication sequence. The reliability of these as yet undeveloped circuits is anticipated to be a major concern that is best addressed early in their development, since the failure phenomena are anticipated to be inextricably tied to the fabrication process employed at the microscopic level.

For these reasons, the first priority in microcircuit fabrication was given to the refurbishment and upgrading of up to six university centers for microcircuit fabrication, with a second priority of augmenting two university reliability research centers to work closely on this new class of circuits.

In a separate, but related, research area, reliability at the systems level is perceived to be threatened today by the susceptibility of advanced solid state circuits to electromagnetic interference at relatively modest power levels. Research into hardening weapons systems against intentional enemy electromagnetic interference or inadvertent disruption by radiation from nearby friendly systems is required. The facilities for enabling university participation in this research include anechoic chambers and electromagnetic measurement instrumentation as a first priority, and dedicated computational facilities for modeling as a second priority.

B.2. Engineering

Engineering encompasses the disciplines usually associated with university departments of mechanical engineering, aeronautics and astronautics, civil engineering, industrial engineering, and materials engineering. The subject matter frequently overlaps that of the other disciplines, such as Materials or Chemistry, but is usually closer to a specific end application or requirement. For example, composite structures is a thrust area that has the same ultimate goal as Materials research on structural composites, namely lighter weight and stronger structures for building weapons platforms. The distinction is the focus in Engineering on determining the performance of composites through innovative design and analysis of structures using state-of-the-art materials. Research results are fed back to materials scientists to provide guidance to their endeavors. A base of knowledge about optimal design methods is thereby developed for application to many problems. Proceeding with this example, non-destructive evaluation (NDE) techniques must be developed to enable the engineer to perform these measurements in support of the analysis of composite structures. There is considerable resultant interaction with the materials scientists who also need NDE techniques to evaluate their progress in controlling the composition of materials.

Similarly, the area of Energetic Materials and Combustion involves considerable interaction with chemists to improve propellants, explosives, and fuels. The facilities in these two areas are typically large and have a significant element of concern for the safety of the personnel performing the research. The instrumentation is becoming dominated by lasers and analytical tools similar to that needed in Materials science.

Fluid mechanics and acoustics are the classical, almost exclusive, domain of Engineering, with slight involvement by molecular and chemical

physics. The facilities are typified by dedicated wind tunnels and water tunnels. Instrumentation is dominated by automatic digital data acquisition and digital computer modeling and simulation of the phenomena. Laser probes and acoustic sensors with sophisticated signal processing are also mainstays of instrumentation in this discipline.

Manufacturing, design, and reliability have increasingly been moving toward a computer-dominated emphasis on graphics, design aids, expert systems for process control, artificial intelligence to relieve pilot workload in single seat helicopters, and self diagnosis and self repair of machines and weapons systems. Classical industrial engineering, computer science, and structural engineering are very much coming together in this field. The facilities are replicas of factory workcells or simulators of aircraft cockpits and the instrumentation is heavily computer networked. The Defense Advanced Research Projects Agency (DARPA) is making advanced teleconferencing equipment available to several university centers in robotics so they may test their algorithms for robot vision on the DARPA autonomous land vehicle located at a contractor facility. They will also plan to provide replicas of a fingered robot hand to many of these university research centers. Non-destructive evaluation for manufacturing process monitoring and control, as well as for inspection of finished parts and fielded systems, requires a comprehensive research program, which would best be accomplished through a center of excellence in non-destructive evaluation/characterization.

Soil mechanics is uniquely supportive of blast hardened silos, construction, maintenance, and repair of runways, and priority command, control, and communications centers. The facilities at universities are presses, shock tubes, or high-G centrifuges.

B. 4. Materials

Materials research includes the growth of semiconductor, magnetic, and optical materials, as well as processing and fabrication of structural materials such as metal alloys, ceramics, and composites. The processing of semiconductor materials into electronic and optical devices and circuits is reported under Electronics, while the testing of structural composite materials and non-destructive evaluation for both manufacturing and in-process control of materials is reported under Engineering. This traditional division of research responsibility has begun to blur in recent years, and multidisciplinary research teams have been forming in recognition of the strong interaction between material growth, component fabrication, and ultimate system performance. In fact, for optimum coordination, the facilities requirements reported in this section for compound semiconductor growth should be co-located or closely adjacent to the microelectronic fabrication and reliability facilities reported under Electronics.

The greatest potential payoff and also the greatest investment costs are perceived by DOD materials research managers to be associated with two areas: the growth of compound semiconductors and the fabrication of advanced structural composites. High priority at somewhat reduced investment is given to facilities for optical and magnetic materials and for research on structural ceramics.

Compound semiconductor growth has received only a small fraction of the scientific and technical attention that has been spent on silicon. This has been entirely justified to date, since silicon possesses excellent electrical, thermal, and chemical properties, especially with its high quality native oxides and silicides. Being an elemental semiconductor, silicon is significantly simpler from a device processing standpoint than the compound semiconductors, such as gallium arsenide, cadmium telluride, and alloys, e.g. gallium aluminum arsenide and mercury cadmium telluride. The steady doubling of the capability of silicon integrated circuits every two to four years for the past twenty years is evidence of the wisdom of this research investment strategy. It is only recently that the material property limitations of silicon have presented a serious limit to device performance. Research attention is currently turning to at least three ways to get around this limitation. One approach is mentioned in the Electronics section, having to do with new device physics associated with ultra small device dimensions. A second approach, for information processing, is to use artificial intelligence to make "smarter" rather than just "faster" computers. The third approach is to turn significant resources toward the growth and characterization of the compound semiconductors. The facilities investment that is detailed here would permit four to seven university centers to advance the technology of compound semiconductors for signal detection, signal processing, millimeter waves, and communications, to name just a few DOD priority applications.

Composites materials have similar exciting potential for structural applications, ranging from high strength, lightweight airframes and large space structures to lightweight armor for highly mobile combat vehicles. These materials utilize high strength fibers embedded in polymeric, metal, or ceramic matrices. The creation of the fiber itself and the interaction between the fiber and the matrix during the processing largely determine the performance and reliability of the composite when exposed to harsh military environments over its service life. Only recently have advances in analytical tools permitted the microscopic characterization of these materials, both physically and chemically. These tools are both elegant and expensive. The facilities investment detailed here would establish, through new construction and refurbishment, six centers of university research on structural composite materials.

Optical materials are beginning to emerge in communications and signal processing applications. The advances that have been made in optical waveguides using silica glass exemplify the success possible through materials processing research. The combined stringent requirements for low transmission loss and very high tensile strength were achieved through research linking materials structure, properties, and performance. Magnetic materials in bulk form are widely used in critical electrical components, such as electromechanical switches and microwave phased array transmitters and receivers. In thin film form, magnetic materials are used for recording media and non-volatile memory. The facilities investment described here would establish two university centers in optical materials and would augment one existing university center in magnetic materials.

Structural ceramics research of high quality is performed in a number of small university laboratories that are in need of refurbishment and expansion to apply modern microstructural analysis techniques to

processing of high temperature ceramics for hostile environments. Both bulk ceramic components, such as radomes for high velocity aircraft, and ceramic coatings on turbine engine components would benefit from this upgraded research capability.

Finally, it should be noted that a segment of the materials research community is dependent upon support from very large research facilities, such as synchrotron and neutron sources. None of these facilities are included in this report. The predominant funding for these national facilities comes from NSF and DOE, with only minor support from DOD. Any decrease in support of these facilities by the other agencies would severely affect the DOD Materials research program.

B.5. Physics

Research on new and improved sources of electromagnetic radiation is a major component of the Physics program of DOD. The free electron laser is a direct result of high risk research funded by DOD. It has demonstrated an entirely new mechanism for generating coherent radiation that is freed from the usual constraints imposed by the need for a material medium. This device has already demonstrated that very wide tunable bandwidth is possible; this has great implications for its utility as a scientific research tool in the analysis of materials, and as a frequency agile radiation source for potential military applications, such as communications and target tracking. Recirculating the electron beam in storage rings offers theoretically high efficiency and hence the potential of high power free electron lasers for directed energy weapons application. The facilities investment reported in this section under coherent radiation sources would refurbish and upgrade three to four existing laboratories performing research on these novel sources.

More conventional lasers for a variety of wavelengths are being explored as tools for research on ultra small integrated circuits, optical computing, catalysis, and molecular biology and for tactical warfare applications such as target designation, optical jamming, and covert communications. The first demonstration of the use of a finely focused laser beam to deposit micron-sized metal connecting lines on semiconductor surfaces occurred under DOD sponsorship in the last five years. It was immediately picked up by the integrated circuit manufacturers as a tool for repairing defects in expensive integrated circuits, and in the photomasks used to produce the circuits. Prior to this breakthrough, lasers had only been used to remove excess material from circuits by vaporizing short circuits and trimming resistors to tolerance. This research continues today under DOD sponsorship and is demonstrating novel methods of doping circuits and of depositing insulators and conductors.

Other laser research projects are attempting to leapfrog over the limitation foreseen in silicon integrated circuits that results from the fact that as much as three-quarters of the surface of these circuits is devoted to metal interconnecting lines between the hundreds of thousands of constituent transistors. The propagation delay of the signals moving on these interconnects at the speed of light is becoming more important in determining the circuit speed than is the switching speed of the transistors. Optical computing chips afford the prospect of distributing the signals by laser beams to many portions of the circuit simultaneously,

thereby avoiding the input-output bottleneck of electrical integrated circuits. The facilities reported under optical communications and spectroscopy in this section would establish a new center for optical circuitry and would upgrade an existing laboratory for optical communications.

Directed energy devices require large facilities for research. The high voltages and currents required can only be stored and switched by physically large components as dictated by the scaling laws of electrical power engineering. To some extent this represents a departure from the usual scale of university research funded by DOD, since "big physics" is usually supported by NSF or DOE. DOD has funded university centers in pulsed power, but this has represented only approximately 10 percent of the physics budget. The facilities described under directed energy devices would expand the existing pulsed power centers and upgrade other centers for research on accelerators and microwave and millimeterwave high power sources. Beam propagation and the interaction of electromagnetic energy with materials would also be studied at these centers.

Astrophysics research directly produces knowledge of the background radiation against which space objects must be detected. Secondarily, the advances in instrumentation (optics, infrared, and x-ray) needed to conduct this research improve our military capability to detect and track space objects and to detect nuclear events in space. The major facility upgrade in this section, and indeed, the single highest cost item in the entire report is a $150M high angular resolution imager center whose goal is a hundred-fold increase in image sharpness on celestial objects and space vehicles.

C. SUMMARIES

Laboratory facilities and equipment needs for thrust areas associated with the foregoing disciplines are given in the following summaries. The science and technology implications of laboratory enhancements, and their national security consequences are also addressed.

CHEMISTRY

Thrust Area: Laser Chemistry

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	20,000	3,000
	-- Priority 2 --	
New construction	75,000	9,000
Renovation/expansion	150,000	13,500
Subtotal	245,000	25,500

Equipment: Linear accelerator and storage ring electron sources; upgrade equipment for free electron laser facility to enhance short wave-length beam power; arrays of six lasers (dye, argon ion), with diagnostic, data processing, and beam direction equipment for each of 15 laser chemistry centers.

Priority	Cost ($ thousands)
1	7,000
2	30,000
Subtotal	37,000

Total Cost: $62,500,000

Technical Objectives and Opportunities:

-- Priority 1 --

An upgraded free electron laser laboratory would be established. It would be a high power, high time resolution facility essential to progress in chemical reaction kinetics, surface physics and chemistry, hot carrier electron transport investigations, and high resolution photo emission studies.

-- Priority 2 --

Fifteen laser chemistry centers would be established. This number represents a best estimate of university community requirements to ensure that DOD-sponsored research in the field is conducted in an efficient, cost-effective manner. Centralized laser resources would facilitate the sharing of expensive instrumentation and permit a reduction of maintenance costs through the pooling of technicians and shop facilities. The centers would include picosecond lasers which, especially in the ultraviolet region, offer a new tool for studying the dynamics of chemical reactions.

National Security Consequences: Fundamental knowledge of chemical reactions is crucial to much of military technology, e.g., to the improvement of propellants, explosives, fuels, lubricants, and high energy lasers.

CHEMISTRY

Thrust Area: Polymeric Materials

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	15,000	2,000
	-- Priority 2 --	
New construction	170,000	20,500
Renovation/expansion	17,000	1,700
Subtotals	202,000	24,200

Equipment: Polymer molding; film casting; film and fibers drawing/orientation equipment; integrated scanning transmission electron microscopes and x-ray detector systems; SQUID magnetometers; picosecond spectroscopy systems; Fourier transform nuclear magnetic resonance units; electrophoresis equipment; data processing and analysis instrumentation; dedicated computer resources.

Priority	Cost ($ thousands)
1	7,000
2	3,350
Subtotal	10,350

Total Cost: $34,550,000

Technical Objectives and Opportunities:

-- Priority 1 --

Laboratory upgrades would provide significant capabilities for new polymer research at the molecular level, heteroatom polymer synthesis and characterization, characterization of polymers for electronics, etc. Focused centers would be established for the development of a) a new generation of polymers for electronics, optical, and magnetic applications, and b) composite materials with unprecedented toughness and high temperature capabilities.

-- Priority 2 --

The proposed expenditures would greatly enhance research in the areas of composite materials, ordered structural polymers, and polymer thin films for electronics applications. This in turn would lead to the development of improved dielectrics, capacitors, and electroactive polymers for uses such as piezoelectric sensors.

National Security Consequences: Polymer materials are essential elements of virtually all strategic and tactical weapons systems. High temperature metal matrix and ceramic matrix composites for applications such as radiation-hardened structures and gas turbine blades require high temperature fibers. Other applications include cheap, expendable acoustic detectors for sonic buoys, and a variety of electronic microdevices. Improvements in polymeric materials would enhance the performance, reliability, and maintainability of a wide array of weapons systems and logistics equipment.

ELECTRONICS

Thrust Area: Microelectronic Fabrication and Reliability for Unique DOD-Critical Devices/Materials

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	60,000	30,000
Renovation/expansion	60,000	15,000
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	20,000	4,000
Subtotal:	140,000	49,000

Equipment: Vacuum and plasma deposition; electron beam and x-ray lithography; plasma etching; wet chemical etching; impurity analysis with electron and ion beams; computational support for device modelling and process simulation; environment simulators for temperature, humidity, vibration, and synchrotron light source for surface diagnostics.

Priority	Cost ($ thousands)
1	30,000
2	6,000
Subtotal:	36,000

Total Cost: $85,000,000

Technical Objectives and Opportunities:

-- Priority 1 --

Provide vibration-free facilities for extremely small feature-size (one hundred angstrom) micro-circuit fabrication of devices utilizing technology beyond VHSIC. Electron-beam and x-ray lithographic equipment and plasma and laser enhanced photo deposition apparatus are required. Electron and ion-beam imaging systems for measurement analysis of ultra small structures are necessary.

-- Priority 2 --

Establish research capability in reliability of micro-circuit devices, especially with respect to temperature, humidity, and radiation hardness of ultra small devices. Expand synchrotron analysis capability for analysis of electrical contacts and other natural interfaces.

National Security Consequences: Integrated circuit fabrication is pressing the limits of our knowledge of chemistry and physics, particularly of interfaces between materials, and the utilization of unique materials for DOD devices. Research to provide the knowledge required for further advances in integrated circuits can only come if researchers in university laboratories have access to state-of-the-art fabrication equipment and processes. Reliability of military systems using integrated circuits depends to a large extent on the processes used to fabricate circuits and their stability over time.

ELECTRONICS

Thrust Area: System Robustness and Survivability

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost $ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	10,000	4,000
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	5,000	2,000
Subtotal:	15,000	6,000

Equipment: Electromagnetic generators; anechaic chambers; microwave measurement equipment; propagation ranges; computation facilities for modelling and diagnostics.

Priority	Cost ($ thousands)
1	3,000
2	2,000
Subtotal:	5,000

Total Cost: $11,000,000

Technical Objectives and Opportunities:

-- Priority 1 --

Expand existing facilities for the measurement of electromagnetic propagation, measurement, and system network investigations.

-- Priority 2 --

Provide computational facilities to enhance modeling of electromagnetic interference phenomena.

National Security Consequences: Sophisticated weapon systems are potentially vulnerable to electro-magnetic interference, either consciously induced by enemy forces or unintentionally introduced through radiation from friendly force equipment. Subtle interactions between electronic systems operating on the same platform can degrade performance or completely deny weapon systems availability. Fundamental scientific understanding of means for minimizing these effects is required to supplement the current engineering fixes being pursued.

ENGINEERING

Thrust Area: Combustion

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	57,500	9,250
Renovation/expansion	95,000	8,600
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	9,300	1,250
Subtotal	161,800	19,100

Equipment: Variable high-pressure flow reactors; optical diagnostic instrumentation; chemical analysis instrumentation; vector processors for the simulation of turbulent multiphase processes; dedicated computer diagnostic and analysis capabilities.

Priority	Cost ($ thousands)
1	15,000
2	11,750
Subtotal	26,750

Total Cost: $45,850,000

Technical Objectives and Opportunities:

-- Priority 1 --

Conduct research on improving the energy efficiency of turbine and internal combustion engines, investigate the viability of alternate fuels (e.g., methanol), develop insights into high-pressure, high-temperature combustion chemistry of present and future propulsion fuels, study multiphase turbulent reacting fuels, and observe high altitude and high mach number combustion processes.

-- Priority 2 --

Develop unique facility for studying combustion and plasma phenomena of propulsion systems; anticipated benefits include increased understanding of ramjet and rocket motor instabilities, fire propagation phenomena ignition and flame propagation mechanisms, and plasma/gas dynamic interactions. Upgrade facility for quantitative flow field imaging to advance understanding of phenomena underlying energy conversion, aerodynamics, and propulsion processes.

National Security Consequences: Improve the range, performance, and reliability of aircraft, missile, ship, and land vehicle propulsion systems; enhance payloads, lower operating costs, reduce corrosion and detectable exhaust signatures, increase fuel performance, and reduce engine development time.

ENGINEERING

Thrust Area: Composite Structures

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	5,000	1,180
	-- Priority 2 --	
	N/A	
Subtotals	5,000	1,180

Equipment: Mechanical testing devices capable of multiaxial and variable loading rates in high temperature environments; real-time non-destructive ultrasonic, acoustic emission and x-ray radiography testing equipment; high temperature test equipment with associated data processing and dedicated computational capability.

Priority	Cost ($ thousands)
1	3,420
2	---
Subtotal	3,420

Total Cost: $4,600,000

Technical Objectives and Opportunities:

-- Priority 1 --

Composite materials have not been exploited to the degree possible, due to a lack of detailed understanding of their response to complex loading conditions, high strain rates, and hostile environments. The proposed facility would likely engender major advances in the understanding of the thermomechanical behavior and failure characteristics of composite materials, with emphasis on high temperature conditions.

-- Priority 2 --

N/A

National Security Consequences: Military applications of composite materials include engine hot sections, nozzles, missile nose cones, aircraft surfaces, lightweight high-strength materials, etc. Improved materials are key to enhancing the performance and maintainability of weapons systems and logistics equipment.

ENGINEERING

Thrust Area: Energetic Materials

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	---	1,000
	-- Priority 2 --	
	N/A	
Subtotals	0	1,000

Equipment: Mechanical and x-ray diagnostic devices; time-resolved optical spectrometer; electromagnetics effects sensor; gas guns; sample preparation equipment; specialized machine shops.

Priority	Cost ($ thousands)
1	7,000
2	---
Subtotal	7,000

Total Cost: $8,000,000

Technical Objectives and Opportunities:

-- Priority 1 --

A primary objective is the development of a broad class of high performance propellants. A second priority objective is research on energetic materials (explosives, propellants, etc.) which remain inert under shock conditions. This involves theoretical and experimental investigations of atomic and molecular processes in shocked condensed wave materials. Experimental research would provide time-resolved optical, x-ray, electrical, and mechanical diagnostics on materials stimulated by mechanical impactors or lasers.

-- Priority 2 --

N/A

National Security Consequences: Inadvertent ignition of explosives and propellants under mechanical shock and thermal stress is a significant operational hazard, particularly under combat conditions. The development of energetic materials which a) are relatively inert to those stresses, and b) function optimally on command, would mitigate this problem.

ENGINEERING

Thrust Area: Fluid Mechanics and Acoustics

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	7,000	650
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	---	350
Subtotals	7,000	1,000

Equipment: State-of-the-art instrumentation for physical acoustics research including highly stabilized lasers, cryogenic equipment, and digital processing gear for automating signal detection and data processing; instrumentation and support equipment for wind and water tunnel facilities for the upgrading of data acquistion and reduction capabilities. For water tunnels, traverse mechanisms, non-linear wave generators, current generators, and related measuring instruments are needed. Wind tunnel requirements include a multi-axis, three-dimensional laser doppler anemometer, and equipment for generating oscillatory flows.

Priority	Cost ($ thousands)
1	3,600
2	3,350
Subtotal	6,950

Total Cost: $7,950,000

Technical Objectives and Opportunities:

-- Priority 1 --

-- Wind tunnels facilities - provide a national resource for studying turbulent and unsteady flows in Reynolds number regimes typical of subsonic flight, and a second facility devoted to the study of the physics of separated flows and transitioning boundary layers. This research could lead to the development of revolutionary concepts of, and predictive methods for, flow management and control in the flight vehicle environment.

-- Water tunnel facility - upgrade an existing facility to greatly reduce flow noise inherent in present tunnel configurations. This improvement would facilitate research on reducing flow noise due to turbulent boundary layer flow around ship hulls.

-- Priority 2 --

-- Wind tunnel facilities - modifications at two sites to facilitate a) research on the prediction of the transition from laminar to turbulent flow

and its impact on vehicle drag, and b) low turbulence flow phenomena with emphasis on associated viscous effects, leading to improvements in aircraft design and control technology.

-- Studies of nonlinear surface wave mechanics to enhance understanding of wave/wave/current interactions, ocean wave/ship wake interaction processes, and associated underwater acoustics, leading to improvements in ship designs, wake signature reduction, etc.

-- Integrated physical acoustics laboratory to facilitate research in sound propagation and attenuation, molecular and chemical physics, and underwater acoustics.

National Security Consequences: The proposed facilities enhancements would support research critical to improved aircraft performance, range, payload, and fuel efficiency. Defense applications of water tunnel upgrades include improved range and performance of ships (surface and submersible), reduction of noise signatures of submarines, and enhanced performance of acoustic sensors through the reduction of host-sensor interference.

57-279 O - 87 - 46

ENGINEERING

Thrust Area: Manufacturing, Design, and Reliability

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	77,000	9,250
Renovation/expansion	55,000	6,250
	-- Priority 2 --	
New construction	10,000	1,200
Renovation/expaansion	20,000	4,500
Subtotals	162,000	21,200

Equipment: Hardware and software for design of component inspectability and manufacturing process control functions; integration of advanced non-destructive testing capabilities with computer-aided mechanical design methods; modernization of dynamic track facility including electronic sensors and displays, simulators, and noise and vibration sensors; human factors diagnostic equipment; avionics gear; combustion diagnostic equipment.

Priority	Cost ($ thousands)
1	10,000
2	3,000
Subtotal	13,000

Total Cost: $34,200,000

Technical Objectives and Opportunities:

-- Priority 1 --

Advances in manufacturing methods having DOD-wide implications for reducing weapons system life-cycle cost, and for enhancing systems reliability, would be pursued. Ancillary objectives include reduced lead times and product development costs, improved productivity and quality control, and reduced inventory costs. A new, unique interdisciplinary manufacturing technology facility emphasizing optimal materials utilization and product reliability would be established. Emphasis would be placed on applications of artificial intelligence concepts to the manufacturing cycle. A second laboratory would be developed for studying the application of computers to the design, manufacture, and control of complex systems, and for the development of advanced composite materials.

Integrated, coordinated research into all aspects of rotorcraft design, manufacturing, and performance at two laboratories is a second objective of the proposed expenditures. Areas of concentration include computer-aided design and manufacturing of rotorcraft components, the study of human

factors problems associated with the workload of single pilots in a high performance rotorcraft, stability and control research, and combustion studies aimed at enhancing engine performance.

-- Priority 2 --

Factory of the future concepts would be explored combining manufacturing physics and artifical intelligence, with emphasis on the development of unmanned, self-diagnostic, and self-repairing machines and robots.

Upgrades of two more rotorcraft labcratories addressing the technical issues outlined for Priority 1 would be made possible, with emphasis on rotorcraft dynamics and avionics, respectively.

National Security Consequences: Procurement and maintenance cost-containment are key considerations in the DOD budget. The proposed facilities would support research directed toward these goals. Improved quality control would enhance product reliability. Army mobility rests to a great extent on rotorcraft (helicopter) performance capabilities, including speed, lift capacity, payload, and crash-worthiness. The proposed facility expenditures would address all of these factors in a much more comprehensive manner than is now feasible.

ENGINEERING

Thrust Area: Soil Mechanics

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
	N/A	
	-- Priority 2 --	
New construction	6,000	1,600
Renovation/expansion	---	---
Subtotal	6,000	1,600

Equipment: Four hundred G-ton centrifuge with support apparatus.

Priority	Cost ($ thousands)
1	N/A
2	200
Subtotal	200

Total Cost: $1,800,000

Technical Objectives and Opportunities:

-- Priority 1 --
N/A

-- Priority 2 --
The centrifuge would permit the study of soil and structure phenomena in realistic stress regimes not possible with present facilities. The laboratory would be developed to study both static and dynamic loadings.

National Security Consequences: Research would be applicable to the development of improved structures for missile silos and hardened tactical facilities.

MATERIALS

Thrust Area: Optical and Magnetic Materials

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	10,000	3,000
Renovation/expansion	15,000	2,000
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	10,000	2,000
Subtotal:	35,000	7,000

Equipment: Preparation and handling facilities; high vacuum furnaces; computer-controlled annealing ovens; fiber extrusion and cladding apparatus; grinding and polishing equipment; electron beam microscopes; laser diagnostic facilities; secondary ion mass spectrometers; electron spectrometers; Raman surface spectrometers; high field magnets; casting/grinding/magnetic aligning/sintering equipment operating in "oxygen-free" atmospheres.

Priority	Cost ($ thousands)
1	2,300
2	1,000
Subtotal:	3,300

Total Cost: $10,300,000

Technical Objectives and Opportunities:

-- Priority 1 --

Establish two university centers of excellence in optical materials for both fiber-optic applications and integrated optics circuits for signal processing. Facilities should include material growth, device fabrication, and evaluation capabilities. The centers would generate benefits in such DOD high pay-off areas as durable low loss fibers, laser sources in the ultraviolet and visible wavelength ranges, detectors in the 8-14 micron region, vapor processing/deposition processes, non-linear optical materials, etc.

-- Priority 2 --

Expand existing capability in magnetic materials for improvements in field strength and in temperature operating range of rare earth magnet materials. Research emphasis would be on materials characterization and structure definition using Mossbauer, x-ray diffraction, scanning transmission electron microscope, and neutron diffraction methods.

National Security Consequences: Optical materials are assuming greater significance to defense systems for surveillance, laser designation, and high energy laser weaponry. In addition, optical signal processing may provide an alternate to conventional integrated circuits for information processing. Magnetic materials are currently used in microwave transmitting devices, switching devices, and in non-volatile memory systems for crucial military information processing and communciation systems.

MATERIALS

Thrust Area: Silicon and Compound Semiconductor Growth

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	20,000	15,000
Renovation/expansion	40,000	8,000
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	40,000	10,000
Subtotal:	100,000	33,000

Equipment: Molecular beam epitaxy; metal organic chemical vapor deposition electron beam diagnostics; laser probe diagnostics; mass spectrometry.

Priority	Cost ($ thousands)
1	30,000
2	10,000
Subtotal:	40,000

Total Cost: $73,000,000

Technical Objectives and Opportunities:

-- Priority 1 --

Crystal growth facilities for low defect silicon and for device quality gallium arsenide and gallium aluminum arsenide are required. Instrumentation in this area combines growth with evaluation of materials within the same deposition chambers. By contrast, in commercial practice crystal growth of bulk ingots is performed in an activity separate from the evaluation of the grown material. These facilities are extremely expensive and are in the laboratory apparatus phase currently, with few commerical instruments being available.

-- Priority 2 --

Crystal growth facilities for advanced compound semi-conductors such as mercury cadmium telluride are required for the improvement of optical as well as electronic devices. Relatively little research has been done on the application of modern growth techniques to these compounds, largely because of the attention focused on silicon and gallium arsenide.

National Security Consequences: Integrated circuits are at the heart of most modern military systems, from command and control to smart weapons. The VHSIC program has made a major advance in the capability of these devices, by reducing the feature size down to the one micron regime. Future advances in this circuitry will require greater fundamental understanding of the functioning of conventional integrated circuits. For feature sizes even smaller than this, quantum effects will introduce wholly new device phenomena, presenting major opportunities for advancement in information processing capabilty. Examples of technology applications include infra-red focal plane array detectors, integrated optics, millimeter and microwave integrated circuits, and optoelectronics.

MATERIALS

Thrust Area: Structural Ceramics

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	20,000	3,000
Renovation/expansion	5,000	1,000
	-- Priority 2 --	
New construction	30,000	5,000
Renovation/expansion	10,000	2,000
Subtotal:	65,000	11,000

Equipment: Ball milling and mixing equipment; hot isostatic presses; vacuum and controlled atmosphere furnaces; fume hoods; surface analysis equipment; scanning electron microscopes; secondary ion mass spectrometers; x-ray diffractometers; computational facilities for data acquisition and process modelling.

Priority	Cost ($ thousands)
1	9,800
2	5,400
Subtotal:	15,200

Total Cost: $26,200,000

Technical Objectives and Opportunities:

-- Priority 1 --

Three university laboratories currently involved in ceramics research would be upgraded. The primary benefits include enhanced understanding of the fundamental relationships between (a) ceramics constituents and processing techniques, and (b) material properties, reproducibility, and reliability. Elucidation of these governing factors should greatly reduce the time required to develop improved ceramic materials and composites. Principal research benefits envisioned include development of non-destructive evaluation techniques, methods for the deposition of ceramic coatings using plasma techniques, and development of materials which will tolerate severe thermal shock and sustained high temperatures, and which have uniform, reproducible microstructures.

-- Priority 2 --

Three additional laboratory facilities would be expanded in the context of the above rationale.

National Security Consequences: In hostile environments, metal surfaces oxidize, corrode because of stress, fail because of fatigue, exhibit effects from laser radiation and interfacial phenomena, and are subjected to friction and wear. Ceramic materials are used in extremely hostile environments in turbine engines, rocket nozzles, and electromagnetic windows of high velocity aircraft and missiles.

MATERIALS

Thrust Area: Structural Composites

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	50,000	15,000
Renovation/expansion	60,000	8,000
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	80,000	10,000
Subtotal:	190,000	33,000

Equipment: Vapor deposition epitaxy reactors; filament winders; squeeze casting presses; injection molding presses; textile forming looms; thermoforming presses; servo-hydraulic forming equipment; powder processing and fiber growth equipment; special equipment for ceramics processing; high temperature/high pressure autoclaves; process control computers; diagnostic and modeling computers and graphics.

Priority	Cost ($ thousands)
1	20,000
2	20,000
Subtotal:	40,000

Total Cost: $73,000,000

Technical Objectives and Opportunities:

-- Priority 1 --

Establish four major university centers of excellence in the fabrication of fiber and matrix materials, emphasizing polymer matrix and ceramic matrix materials. Capabilities should include fabrication and layup of small samples and diagnostic materials for the analysis of thermophysical and thermomechanical properties.

-- Priority 2 --

Supplement the above with three to four additional university centers with similar missions.

National Security Consequences: Lightweight and high strength composite materials are increasingly being used in aircraft and spacecraft. These materials combine the high strength of ceramic fibers with the ductility of polymeric or metallic matrices. Significant performance advantages have already been obtained through the use of composite materials, including ceramic matrix composites, and further performance advantages are foreseen, particularly with regard to high temperature capability, laser hardness, armor, and low observables.

PHYSICS

Thrust Area: Astrophysics

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
	N/A	
	-- Priority 2 --	
New construction	68,000	11,550
Renovation/expansion	35,000	5,100
Subtotal:	103,000	16,650

Equipment: Radio, optical, and x-ray astronomy equipment; upgrade of 100 inch aperture telescope for active optics and interferometric imaging; high angular resolution imager with one milliarcsecond resolution and optical elements of 7 1/2 meters; 4-meter telescope for optical/infrared imaging and spectroscopy.

Priority	Cost ($ thousands)
1	N/A
2	152,065*
Subtotal:	152,065

Total Cost: $168,715,000

* Includes $150,000,000 for high angular resolution imager.

Technical Objectives and Opportunities:

-- Priority 1 --

N/A

-- Priority 2 --

- Expand laboratory capabilities in radio, optical, and x-ray astronomy to study final stages of evolution of stars, formation of neutron stars and black holes, the occurrence of supernova, and to elucidate recently observed non-thermal radio sources.

- Extend existing capabilities in active optics, speckle imaging techniques, and advanced detector programs to existing telescope to produce diffraction-limited imaging of astrophysical sources.

- Establish high angular resolution imager center which exploits advances in optics, sensors, and computer technology to afford a hundred-fold increase in image sharpness on celestial objects (quasar nuclei, stellar, and solar system object surface features) and space vehicles.

- Develop new optical and infrared telescope/instrumentation for astrophysics applications embodying improved precision pointing and tracking, image quality optimization, advances in optical and infrared technology, high speed two-dimensional photon detectors, etc.

National Security Consequences: Advances in astrophysics-related imaging techniques have important applications for the detection and identification of space and non-space objects of military significance. In particular, the technological development of active optics in combination with speckle imaging will make possible diffraction limited observations of objects through the atmosphere. The enhancement of x-ray instrumentation capabilities has application to the detection of nuclear events in space.

PHYSICS

Thrust Area: Coherent Radiation Sources

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	17,000	2,500
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	---	4,000
Subtotal:	17,000	6,500

Equipment: Tunable two-beam two-stage free electron lasers; millimeter range free electron laser; mode-locked laser and support equipment; spectrographs for optical emission spectroscopy; electronic processing equipment (lithographic, deposition, etching); auxiliary interface and support equipment.

Priority	Cost ($ thousands)
1	1,500
2	6,250
Subtotal:	7,750

Total Cost: $14,250,000

Technical Objectives and Opportunities:

-- Priority 1 --

Laser facilities are key assets for a variety of materials and directed energy related research. The cited expenditures would substantially enhance the capability of universities to explore and expand technology horizons in electronic materials, catalysis, corrosion, and molecular biology, among others. Emphasis is on more broadly tunable lasers, which generate coherent radiation over a wide range of energies. This greatly enhances the flexibility available to researchers for analyzing material properties, particular surfaces, and interfaces of importance to solid state electronics and optoelectronics.

-- Priority 2 --

Laser-guided plasma and electron beam facility upgrades will allow the university community to explore more efficiently and comprehensively heretofore unknown aspects of directed energy propagation concepts.

National Security Consequences: Coherent radiation research is critical to a variety of DOD R&D missions, including the design of directed energy weapons, propagation (e.g., "channeling") of charged particle beams, improvement of high power radar technology and electronic countermeasures, advances in ultra-small electronic devices, optical storage and switching aspects of ultra-fast optical computers, etc. High average moderate power tunable lasers are expected to have important implications for tactical applications related to electronic warfare.

PHYSICS

Thrust Area: Directed Energy Devices

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
New construction	---	---
Renovation/expansion	63,000	13,250
	-- Priority 2 --	
New construction	---	---
Renovation/expansion	20,000	4,000
Subtotal:	83,000	17,250

Equipment: Hardware to enlarge accelerator power supplies and capacitor banks; vacuum tube fabrication equipment; large electric discharge chambers; pulsed power generator; high-power glass laser; dedicated data acquisition and analysis computer facilities.

Priority	Cost ($ thousands)
1	6,250
2	4,000
Subtotal:	10,250

Total Cost: $27,500,000

Technical Objectives and Opportunities:

-- Priority 1 --

- Upgrade stellatron accelerator facility as a testbed for high current, high energy accelerators, including screen room and associated diagnostic instrumentation. Facility would generate data of use in the development of compact, high performance accelerators in the non-linear beam interaction regime.

- Establish center for research on thermionic sources of millimeter wave radiation at megawatt power levels. The facility would provide understanding electron-electromagnetic field interactions leading to the development of Rf sources in a regime extending to 30 THZ.

- Develop high repetition rate, high average power pulsed power facilities to support studies in plasma beam propagation, microwave power generation, and the interaction of electromagnetic radiation with materials.

-- Priority 2 --

- Expand center for research on switches and power conditioners for extremely high voltages and high currents. Research in this area is heavily dependent on the existence of specialized facilities.

National Security Consequences: Compact high current, high energy accelerators are key components in charged and neutral particle beam weapons concepts. Thermionic radiation sources are essential components of and/or have implications for fusion power sources, directed energy weapons, and spacecraft vulnerability questions associated with ion clouds in space. High voltage and high current switches, regulators, and storage devices are required to operate directed energy weapons. The development of repetitive and reliable opening switches would remove significant impediments to the practical implementation of all directed energy devices.

PHYSICS

Thrust Area: Optical Communications and Spectroscopy

Laboratory Needs

Facilities:	Building Requirements (gross ft^2)	Total Facility Cost ($ thousands)
	-- Priority 1 --	
	N/A	
	-- Priority 2 --	
New Construction	8,000	1,000
Renovation/expansion	---	---
Subtotal:	8,000	1,000

Equipment: Lasers (stable argon ion, ring, picosecond CO_2, femtosecond dye and YAG, mode-locked glass); transient digitizers; computational and digital signal processing capabilities; scanning electron microscope; optical components with special coatings.

Priority	Cost ($ thousands)
1	1,550
2	950
Subtotal:	2,500

Total Cost: $3,500,000

Technical Objectives and Opportunities:

-- Priority 1 --

Laboratory upgrade would facilitate research leading to a better understanding of the fundamental processes and interactions in semiconductors and microstructures necessary for the development of ultra-fast semiconductor electronic devices.

-- Priority 2 --

- Laboratory improvement would permit detection of weak signals which arise in many photon statistic experiments. For example, the creation of photon pairs through non-linear processes followed by subsequent simultaneous detection (i.e. correlation experiments) generally produces weak signals. Such phenomena could greatly expand communication signal detection capabilities.

- A Center for Optical Circuitry would be established for optical computing. It offers the possibility of great advances in computing speed, capacity, and degree of parallelism over electronic computing. Dramatic new computer architectures are possible, e.g., three-dimensional logic and storage.

National Security Consequences: A wide variety of defense-related technology improvements are based on progress in the development of extremely fast and compact electron devices for digital and analog applications. These include smart weapons and surveillance systems. In addition, secure optical communications have important applications to C3.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

A. DISCUSSION

The laboratory needs cited in Chapter IV relate to universities already heavily involved in conducting research for DOD. They represent a small subset of the 157 colleges and universities addressed in Tables III-4 and 5, and an even smaller segment of all research universities included in Tables III-2 and 3. The AAU study summarized in Table III-1 equates with this work most readily in terms of the number of institutions covered.

Summary comparisons follow between the prior laboratory assessments cited in Chapter III and the present work given in Chapter IV. It should be emphasized that these comparisons involve the DOD-specific laboratory needs developed in this report as opposed to more general needs addressed in prior studies. Nonetheless, they suggest that the cumulative expenditures discussed in Chapter IV are of reasonable magnitude in the context of general university laboratory needs identified in other studies.

- The AAU data shown in Table III-1 relate to 15 universities, a figure roughly equivalent to the average number of institutions encompassed by defense-related laboratory needs for each of the disciplines cited in Table IV-1. This probably accounts for the fact that, for some disciplines, defense-related totals substantially exceed the AAU report figures. Interpretations of these comparisons must be tempered by the fact that the discipline-specific university populations encompassed within the present study differ markedly from the AAU sample population. A Comparison of Tables III-1 and IV-1 indicates that the defense-related facilities needs cited in this report constitute 43 percent of the AAU Chemical Sciences projections for the period 1982-84, over 100 percent for Engineering (encompassing the Electronics, Engineering, and Materials categories of Table IV-1), and 55 percent for Physics. For projected equipment needs, those of this study exceed the AAU figures by factors of roughly three and six for Chemical Sciences and Engineering. The numbers are comparable for Physics, excluding the astrophysics high resolution imager cited in the present study.

- According to NSF staff, an estimated 50 percent to 70 percent of the $221 million cited in Table III-2 for 1983 university capital expenditures (research and instructional) was devoted to research laboratory facilities. Assuming, for purposes of comparison, a 60 percent figure, 1983 research laboratory expenditures for all universities in the engineering and physical science disciplines total $133 million. To obtain a roughly comparable figure, one can annualize the $275 million of defense-related engineering and physical sciences facilities needs (Table IV-1) over a five-year period. This yields an annual expenditure rate of $55 million. It represents slightly more than 40 percent of the estimated $133 million spent by all universities.

- Research equipment expenditures for all U.S. colleges and universities are summarized in Table III-3 for Engineering, Chemistry, and Physics and Astronomy. Engineering expenditures average approximately $70 million for the two-year period. The NSF Engineering category compares roughly to the combined Engineering, Electronics, and Materials categories of this report, where priority 1 and 2 equipment needs shown in Table IV-1 total almost $200 million. If the $200 million is annualized over a five-year period, approximately $40 million in FY 85 dollars would be spent for defense-related equipment annually. This represents over 55 percent of the average 1982-83 engineering annual equipment expenditures for all higher education institutions. Similar analyses for physics and chemistry suggest that needs in these areas cited in Table IV-1 pro-rated over five years are approximately $35 million and $9.5 million, respectively. The projected annual physics expenditure is roughly equal to the NSF 1982-83 average for all universities, largely due to a $150 million high resolution imager for astrophysics. Similarly, the projected chemistry annual expenditures are 30 percent of the average for all U.S. universities for the two-year period.

- Column two of Table III-4 lists 1982 research equipment expenditures for the top 157 research universities. As in Table III-3, the NSF Engineering category compares roughly to the combined Engineering, Electronics, and Materials categories of this report, whose equipment needs total approximately $200 million. Assuming again that expenditures for defense-related laboratory equipment needs would be spread over a five-year period, approximately $40 million in FY 85 dollars would be spent for this purpose annually. This represents roughly 45 percent of the 1982 expenditures for the 157 universities. Similarly, the five year annual expenditure level for physics from Table IV-1 is over 60 percent of the 1982 equipment purchase level, largely due to the inclusion of the aforementioned $150 million high resolution imager for astrophysics applications. The five-year expenditure level implied for chemistry in Table IV-1 is $9.5 million, or approximately 25 percent of the stated 1982 expenditures by the 157 universities.

- The replacement value of "academic research instrument systems in active research use" for the aforementioned 157 universities is given in Table III-3 in terms of 1982 dollars (Column 4). With an inflation factor of 1.076 applied to the 1982 costs, Table V-1 gives priority 1 and 2 (total) defense-related equipment needs from Table IV-1 expressed as percentages of Table III-5 replacement values. As before, the NSF Engineering category encompasses the Electronics, Engineering, and Materials categories of this report. For the Engineering and Physics and Astronomy categories, stated defense-related needs are quite substantial in comparison with the NSF equipment replacement figures. The Chemistry percentage is substantially lower, perhaps reflecting a proportionately lesser DOD involvement in broad aspects of experimental chemistry.

Table V-I

Defense-related university laboratory equipment needs (Table IV-1) expressed as percentages of replacement costs for all research equipment at 157 leading research universities (Table III-5)

Field of Research	% of Replacement Value
Chemistry	15
Engineering	44
Physics and Astronomy	68

B. RECOMMENDATIONS

A total of $300 million over a five (5) year period is proposed for the upgrading of university laboratories.

1. The priority 1 laboratory facilities needs cited in Table IV-1 should be addressed with incremental funding of a five-year $150 million initiative. The initiative should be a part of, and administered through, the existing contract research programs of the OXRs and DARPA. It is believed that this is the most efficient mechanism for targeting facilities improvement funds toward the highest DOD research priorities. This program would be of equal magnitude (i.e. $150 million expended at an annual rate of $30 million) to the existing University Research Instrumentation Program (URIP) pertaining to equipment, but would be allocated as facilities-earmarked increments to competitive research awards. It would thus differ from URIP in that it would not require the establishment of separate review and award mechanisms. It should be stressed that, in the best interests of national security, neither equipment nor facilities upgrade programs should be funded at the expense of existing OXR and DARPA competitive research programs. Further erosion of the latter would jeopardize the scientific basis for future technological innovation on which our national security depends.

2. The existing URIP program should be extended by three years at its present level of $30 million per year. This, combined with the remaining two years ($60 million) of the present program, would constitute the $150 million required to address priority 1 equipment needs (Table IV-1).

3. Priority 2 laboratory needs should be addressed as a national issue with the involvement of other federal agencies having an impact on the national science and technology base, i.e. the National Science Foundation, NASA, Department of Energy, etc.

4. Very large items of equipment and/or facility needs, e.g. the $150 million astrophysics high resolution imager cited in this report, should be addressed on their merits as individual appropriations rather than as parts of broader, more general funding initiatives.

APPENDIX

STUDIES OF ACADEMIC FACILITIES*

Study	Description of Study	Findings
"Health Related Research Facilities in the U.S. in the Nonprofit Nonfederal Sector" Study by Westat Corporation for National Institute of Health (NIH) (1969)	Survey study to gather data on the amount, age and ownership of space in 1968, the amount of space under or scheduled for construction and the estimated space needed to eliminate overcrowding by 1980	10 m. of 42 m. sq. ft. in unsatisfactory condition -over 50% available space in poor condition -additional 55 m. square feet of space needed by 1980, with 17 m. square feet requiring remodeling
"Higher Education General Information Survey" (HEGIS) Conducted by the National Center for Educational Statistics (NCES) (1974)	Survey of 3,200 colleges and universities including data to estimate facilities needs	-20% of facilities at surveyed institutions in need of replacement (2.3 billion square feet) -$2. billion needed just for remodeling of facilities
"Health Research Facilities: A Survey of Doctorate-Granting Institutions." Conducted by American Council on Education (ACE) with funding from National Science Foundation (NSF) and NIH (1976)	Survey of 155 Ph.D. granting institutions to gather data on status of academic health research facilities, new construction in progress, and plans for expansion in succeeding five year period	-29% of academic facilities for health research in need of renovation or replacement (23 million square feet) -cost estimates to meet needs: $547 million for 1975; $360 million for each of succeeding five years
"National Survey of Laboratory Animal Facilities and Resources" Conducted by National Academy of Sciences (NAS) (NIH Publication No. 80-2091) (1978)	Survey of 922 nonprofit NIH eligible institutions gathering data to estimate facilities needs	-16% institutions reported need for replacement of facilities -38% reported need for remodeling of facilities -47% reported need for additional space

*Source: Linda S. Wilson, "The Capital Facilities Dilemma: Implications for Graduate Education and Research", to be included in forthcoming Brookings Institution study, Bruce L. R. Smith, editor, The State of Graduate Education, 1985.

STUDIES OF ACADEMIC FACILITIES

Study	Description of Study	Findings
Report of Research Facilities Branch of National Cancer Institute on survey of facilities needs in cancer research Conducted at request of National Cancer Advisory Board (1979)	Survey of 106 institutions receiving National Cancer Institute Support gathering data to evaluate current and future needs for upgrading of cancer research facilities	Funding need of $149 million for the period 1980-1985 estimated for cancer research facilities
"A Program for Renewed Partnership" Prepared by the Sloan Commission on Higher Education (1980)	Commission report on federal government/university relations (No data collected)	-Recommendations for competitive program for facilities research grants; $50 million annually for five years, to be allocated by NSF and NIH, to upgrade research laboratories and equipment
"The Nation's Deteriorating Research Facilities: A Survey of Recent Expenditures and Projected Needs in Fifteen Universities" Conducted by the Association of American Universities (AAU) (1981)	Survey of 15 leading universities gathering data on expenditures for research facilities and major equipment and estimates of funding needs for succeeding three year period for faculty research only	-From 1972-1982, surveyed institutions spent $400 million for facilities construction, repair, and renovation -$765 million needed for facilities and equipment over succeeding three year period just to sustain faculty research activities

STUDIES OF ACADEMIC FACILITIES

Study	Description of Study	Findings
Report on academic facilities survey (in 1980-81 Comparative Cost and Staffing Report) Conducted by Association of Physical Plant Administrators (APPA) (1981)	Survey of 226 institutions with 454 million square feet of academic space to gather data on facilities conditions and projected needs	-$1.85-$2.00/square foot required to eliminate most pressing needs -deferred maintenance need per institution of $9.5 million at universities $1.1 million at four year colleges $.4 million at two year colleges
"Strengthening the Government-University Partnership in Science" Conducted by Ad Hoc Committee of NAS, National Academy of Engineering and Institute of Medicine (1983)	Committee report on federal government/university relations (no data gathered)	-Critical, growing need for replacement of academic science facilities and equipment -recommends comprehensive program for facilities construction and development, acquisition, maintenance and operation of modern equipment
"Adequacy of Academic Research Facilities" Conducted by Ad Hoc Interagency Steering Committee on Academic Research Facilities (April, 1984) National Science Foundation	Pilot study of 25 major research institutions with major study planned to gather data for detailed analysis of the condition of facilities used for science and engineering and medical research. Major study to estimate future needs for construction, remodeling and refurbishment of academic research facilities	-Over succeeding 5 year period all colleges and universities would require about $1.3 billion per year for research facilities alone. (Note: Present level of capital facilities expenditures for academic research, development and instruction is $1 billion per year.)

STUDIES OF ACADEMIC FACILITIES

Study	Description of Study	Findings
Report of Department of Defense (DOD) Working Group on Engineering and Science Education. Prepared by DOD-University Forum (1983)	Working group report on condition and needs of academic science and engineering	Deficiencies in research facilities and equipment acute in most universities
"Report on NIH Experience with Extramural Construction Authority" Prepared by Office of Program Planning and Evaluation, NIH (1983)	Historical comparison of legislative authorities for construction of health research facilities analyzing past facilities funding experiences	-Funding authorities mainly for special, not general, use -Almost all funds made available under grant mechanisms -Recent authorities fail to separate funds for construction and research -None of funding authorities based on systematic analysis of need
"University Research Facilities: Report on a Survey Among National Science Foundation Grantees" Conducted by Division of Policy Research and Analysis, NSF, for Infrastructure Task Group of National Science Board (NSB) (June, 1984)	Survey of 1983 NSF grant Principal Investigators (248 investigators randomly sampled) to determine condition of existing facilities and the impact of facilities on research	-70% facilities had been renovated in last 10 years using 7% Federal $ -50% facilities slated for renovation in next three years -80% of P.I.'s rated safety of facilities as excellent -60% reported having lost some research time in past year due to facilities-related failures; 40% reported graduate students had spent 3 or more days fixing problems created by facilities over past year

STUDIES OF ACADEMIC FACILITIES

Study	Description of Study	Findings
Proposed study of cancer research facilities Conducted by President's Cancer Panel and the National Cancer Institute (Proposed)	Proposed survey study to gather data to inventory the quality and quantity of current research facilities in cancer research	In progress
Facilities Needs in Chemical Science and Engineering Conducted under aegis of the Board on Chemical Science and Technology, National Research Council (In progress)	Survey to ascertain specific facilities data for research and teaching in chemistry, biochemistry, and chemical engineering academic departments	In progress

APPENDIX 5

Department of Energy
Washington, D.C. 20585

August 21, 1984

MEMORANDUM FOR: Assistant Secretaries
Director, Office of Energy Research
Managers, Operations Offices

SUBJECT: Guidelines on Relationships Between the Department of Energy and Universities and Colleges

The Administration's commitment both to national security and strong economic revitalization includes a major emphasis on a strong national scientific and technical base. This emphasis, in turn, requires the active and cooperative participation of the three major Research and Development performing sectors—private industry, the government laboratories and universities and colleges.

The national energy effort, as one major component of the Administration's economic and national security programs, also requires close interaction of scientists and engineers in the three major sectors. University scientists and engineers are particularly important resources to the Department not only in producing new knowledge but also in preparing and training the next generation of scientific and technical professionals. Recognizing the importance of strong university-based participation in our programs, the purpose of this memorandum is to provide general guidance to Department offices and programs on how our relationships with universities and university scientists and engineers should be conducted.

Background:

The National Energy Policy Plan (NEPP) establishes overall goals and strategies for the Department in the planning, development, execution and evaluation of energy programs. The appropriate roles for the Department in supporting research and development are to advance the frontiers of basic scientific and technical knowledge and to support the development of new and alternative energy resources through scientific and technical research for further development and eventual utilization outside the government.

Institutions and organizations responsible for carrying out DOE-supported research programs include private industry, the major contractor-operated research facilities and laboratories, the Department's energy technology centers and universities and colleges. Each performer has important and distinct responsibilities in maintaining a strong technology base in all energy areas. The principal criterion used in selecting performers to carry out DOE research is excellence regardless of the location or type of performer. The competitive process provides assurance that the best research will be supported by the Department.

University Participation in Department of Energy Programs:

Within this research policy context, both the Department's fundamental science and energy research and development programs must continue to actively involve scientists and engineers in universities and colleges. This involvement is a national investment not only in the creation of new knowledge, but also in the education of highly-qualified scientific and technical personnel to meet future national needs. A major emphasis in DOE-university relationships should, therefore, be on supporting university scientists and engineers in the fundamental energy-related sciences and in research which strengthens the technology base in all energy areas. In addition, DOE-supported research should directly enhance the education and training process through the participation of students in research.

Further, DOE staff should encourage and support cooperative research and related programs between universities and industry and between universities and the national laboratories and energy technology centers. It should be noted that each performer, whether university, industry or national laboratory, operates in distinct and different environments. DOE staff should recognize these differences and apply management and administrative systems and techniques compatible with the needs and circumstances of each major performer, consistent with statutory and regulatory requirements.

Policy Guidelines

The following general policy guidelines should be used by DOE staff in developing relationships with the university community and in supporting and administering university-based research and related programs. Departmental staff should, to the extent practicable and appropriate and within legal and regulatory requirements:

- o involve university scientists, as appropriate, in all energy programs with the expectation that they will be significant performers in all disciplines related both to fundamental research and advanced, longer-term technology base research leading to improvements and new developments in the energy technologies;

- o provide appropriate opportunities for university scientists to make recommendations on the planning of energy research and technology development programs;

- o recognize the educational impact and benefits of advanced research by encouraging and providing support, as appropriate, for the participation of students in university research projects;

- o encourage university researchers to develop and pursue unique and innovative concepts and ideas in energy R&D including, where appropriate, research requiring multi and interdisciplinary research teams;

- o encourage interaction and collaboration in energy research among universities and industry, the national laboratories and the energy technology centers, including consideration of and support for joint research projects;

- o provide opportunities for faculty and students in predominantly minority universities, including the Historically Black Colleges and Universities, to participate in DOE research, both directly and through the national laboratories and energy technology centers;

- o expand opportunities for university researchers to utilize the special and unique facilities and equipment in the national laboratories and the energy technology centers;

- o work towards ensuring more consistent execution and administration of university research grants and contracts among all the cognizant field procurement offices; and

- o conduct the Department's overall relationships with the university community in a manner which reflects understanding of the special role of universities in education and research and avoids imposition of burdensome administrative requirements wherever possible.

Administrative Guidelines

The following administrative guidelines should be used in carrying out the policies stated above:

- o In addition to responding to competitive solicitations, university scientists should be encouraged to submit unsolicited research proposals to all programs. Program staff should make a concerted effort to provide appropriate advance information and guidance on agency objectives and programs relative to the type of effort contemplated by university scientists.

- o Specific staff members in Headquarters program offices, the energy technology centers, the operations offices, and the multiprogram national laboratories should be designated as initial points of contact for university scientists and administrators seeking information on research opportunities. These staff members will be generally familiar with program R&D needs, interests and procedures for handling and executing university proposals and awards.

- o DOE-sponsored research projects should recognize the special educational responsibilities of universities and normally should avoid support for shorterm, subprofessional types of work that do not contribute directly or significantly to the university's educational mission.

- o Reasonable continuity of university research projects should be maintained. Programmatic and administrative attention to timely award renewals and the use, where appropriate, of multiyear awards will help minimize adverse and burdensome effects on faculty and students and on the institution. Abrupt changes in the funding and monitoring of ongoing university research projects should be avoided wherever possible.

- o Reporting and other administrative requirements on university research projects should be held to the minimum consistent with effective implementation of business and program management oversight responsibilities.

The responsibility for strengthening existing and developing new university research programs rests with each Program Assistant Secretary and the Director of the Office of Energy Research. Each Assistant Secretary/Office Director is responsible for ensuring there are adequate opportunities for university participation in the programs under his/her jurisdiction. The Assistant Secretary for Management and Administration is responsible for ensuring that administrative and business management requirements on university research projects are applied as consistently as practicable and at the minimum level necessary.

I have asked the Director of the Office of Energy Research to report to me periodically on the extent the principles of this statement have been carried out. As necessary, he will prepare recommendations on how university participation in Departmental programs may be strengthened and improved.

Donald Paul Hodel

DONALD PAUL HODEL

cc: Directors, Multiprogram and
Program-Dedicated Laboratories

THE SECRETARY OF ENERGY
WASHINGTON, D.C 20585

July 5, 1984

MEMORANDUM FOR Assistant Secretaries
Director of Energy Research
Managers, Operations Offices

SUBJECT: Policy Guidance for FY 1985-FY 1990 Multiprogram Laboratory Institutional Planning

The quality and usefulness of the multiprogram laboratory institutional plans have improved considerably since the first implementation of the formal planning process in 1978. Further improvement of the plans now depends upon improved mission definition for each laboratory and on improved program planning by the Department. I believe that the generic role of the multiprogram laboratories, recently approved by the Laboratory Management Council, constitutes a sound basis for defining laboratory missions (Attachment I). This role is to conduct high quality, nationally important basic research and applied research and development that, because of its nature, is more appropriately undertaken by national laboratories than by universities or industry. In fundamental research, the laboratories therefore focus on scientific areas of excellence that require large, capital-intensive experimental facilities, or that need sustained effort over periods of many years. In applied research, the focus is on nuclear weapons and defense-related activities, development of energy technologies involving large uncertainties and lead times, or important energy-related environmental factors.

What is needed now is an increasing focus, over the next several planning cycles, on the specific scientific and technical missions at each multiprogram laboratory. Your decisions on the types and levels of technical activity should take into account each laboratory's expertise and capabilities, and should complement other activity within the laboratory system, while maintaining scientific and technical competitiveness. The attached mission statements for each multiprogram laboratory are based on the current institutional plans and have been reviewed by the cognizant Secretarial Officers for consistency with the generic role statement approved by the Laboratory Management Council (Attachment II). I believe that these statements constitute a sound basis for discussion with the laboratory directors and for establishing more focused missions during this current planning cycle.

The Laboratory Management Council has recommended some additional steps aimed at maintaining and improving the effectiveness of the multiprogram laboratory system. As a result, during the past few months, we have issued the Department's policy on appraisal of laboratory performance, guidelines for the use of R&D exploratory funds, refinement of the lead mission assignment process, and a requirement that 5-year program plans include appropriate strategic guidance to the laboratories. These efforts should help to strengthen the institutional planning process and improve our overall interactions with the laboratories.

In addition, there is an important management effort underway aimed at reducing unnecessary and burdensome reporting requirements on the Field to a reasonable level consistent with effective accountability and management. I understand you have contributed to a review of Departmental directives and orders and have recently received a status report on the efforts of the Department to streamline procedures and reduce reporting requirements where possible. I urge you to continue to be involved in this important Departmental effort. It is my hope that it will result in a more effective relationship between the Department and its Government-owned, contractor-operated laboratories; one in which the Government is responsible for determining what is to be done and the contractor for getting it done in a manner consistent with good business practices.

The process for the current institutional planning cycle is underway. The cognizant Secretarial Officers are directing the process for their laboratories and will use it to reach broad agreement on the types and levels of technical activity that will be conducted by each laboratory through the planning period. The Director of Energy Research is coordinating the overall planning process and has issued the Department's schedule and instructions. I urge you in this institutional planning cycle to focus on laboratory technical missions and capabilities, and assign to the laboratories through improved Headquarters program planning, scientific and technical activities that are in keeping with their proper role and unique capabilities.

Donald Paul Hodel

DONALD PAUL HODEL

2 Attachments

ATTACHMENT I

ROLE OF THE
MULTIPROGRAM NATIONAL LABORATORIES

The multiprogram laboratories conduct high quality, nationally important basic research and applied research and development that, because of its nature, is more appropriately undertaken by a Federal laboratory than by universities or industry. In basic research, the laboratories therefore focus on scientific areas of excellence that require large, capital-intensive experimental facilities, or that need sustained effort over periods of many years. In applied research, the focus is on nuclear weapons and defense-related activities, development of energy technologies involving large uncertainties and lead times, or important energy-related environmental factors. The laboratories also maintain for the Government the capability to provide independent scientific advice in their areas of expertise.

This undertaking requires the maintenance of broad multidisciplinary scientific capabilities and the conduct of research and development to support a technology base appropriate to each laboratory's missions. These capabilities are applied to national problems that are generally at the interface between the interests and capabilities of the university and industrial sectors, and that are of sufficient importance, size, term, and complexity to both benefit from and effectively use the laboratories' unique mix of skills and facilities. The laboratories interact and cooperate with the scientific and technical community, where feasible and beneficial, to achieve effective utilization of their unique facilities, to aid in education of scientists and engineers, and to enhance the transfer of technology to the public and private sectors.

Consistent with policies set forth in the National Energy Policy Plan, including strong support for federally-sponsored research and development, the generic role of the multiprogram laboratories can therefore be stated as:

- conduct basic research programs to advance the frontiers of our scientific and technical knowledge in physical and energy-related life and environmental sciences that involve large multidisciplinary teams or major, capital intensive experimental facilities, and provide use of those facilities to members of the scientific and technical community, including interested industry representatives or groups;

- conduct basic and applied research and technology development programs to explore energy technologies and related environmental factors, and develop research options in areas that involve large, unpredictable, and long-term risks, costs, or payoffs, that need development before they can reach the market as competitive energy investment options;

- conduct research, development, engineering, and technical and production support for nuclear weapons, associated nuclear materials, and other defense-related activities;
- provide research and development support, as appropriate, to other Government agencies, and make special capabilities available for public and private sectors on a reimbursable basis;
- contribute, through cooperative programs with universities, to the education of scientists and engineers in the fundamental sciences and all energy-related technologies;
- provide for and encourage the transfer of technology developed at the laboratories to the private and public sectors, and facilitate an interactive climate among the national laboratories and industry.

ATTACHMENT II

MULTIPROGRAM LABORATORY MISSION STATEMENTS

ARGONNE NATIONAL LABORATORY MISSION STATEMENT

The primary mission of Argonne National Laboratory is to carry out applied research and engineering development in nuclear fission and other energy technologies, and scientific research in basic physical and life sciences. This research and development is performed with emphasis on the linking of technology base research with engineering development throughout the concept to application stages. An important part of Argonne's mission is to design and provide research facilities for the benefit of members of the scientific and technical community, and to maintain close interaction with scientific personnel in universities and industry.

To fulfill its mission, Argonne focuses its scientific and technical efforts on: (1) nuclear fission, focused largely, but not exclusively, on the breeder and other advanced reactor systems, with emphasis on steam supply system technologies, advanced power conversion technologies, operation of test facilities, and innovative concepts utilizing inherently safe features and cost-competitive design; (2) nuclear fusion, focused on nuclear systems with emphasis on blanket technology development and materials research; (3) fossil energy, particularly advanced conversion systems with significant development efforts in related technologies; (4) solar and conservation, focused on development of innovative collectors, and energy storage and conversion systems; (5) basic research in physical sciences, focused on multidisciplinary efforts in chemistry, nuclear physics, high energy physics, and materials research; and (6) biological and environmental sciences concerning the effects of nuclear and non-nuclear emissions on living organisms.

BROOKHAVEN NATIONAL LABORATORY MISSION STATEMENT

The primary mission of Brookhaven National Laboratory is to design and provide large, complex research facilities for fundamental scientific studies, and to carry out basic and applied research in energy-related physical, life and environmental sciences. Brookhaven provides use of the laboratory's large and complex facilities to the scientific and technical community, and maintains close interaction with scientific personnel in universities and industry.

To fulfill its mission, Brookhaven focuses its scientific and technical efforts on: (1) high energy physics, presently centered on the operation of the Alternating Gradient Synchrotron; (2) nuclear physics, with current emphasis on heavy ion, kaon, and low energy physics; (3) life sciences research and nuclear medicine, focused on fundamental life processes and their alteration by radiation and chemical pollutants, and on medical applications of nuclear techniques; (4) materials sciences, centered on utilization of the National Synchrotron Light Source and the High Flux Beam Reactor; and (5) chemical sciences, with emphasis on fundamental research into chemical and physical phenomena underlying energy-related transfer, conversion and storage systems.

57-279 O - 87 - 47

IDAHO NATIONAL ENGINEERING LABORATORY MISSION STATEMENT

The primary mission of the Idaho National Engineering Laboratory is to furnish engineering services and products, principally in nuclear energy and associated technologies. Emphasis is placed on those areas which require, or particularly benefit from, the laboratory's unique facilities, geography, environment or expertise. Idaho provides use of its unique facilities for the benefit of members of the scientific and technical community, and maintains close interaction with scientific personnel in universities and industry.

To fulfill its mission, it focuses its scientific and technical efforts on: (1) defense-related nuclear materials production centered largely on receipt, storage and processing of spent fuels, and management of resulting wastes; (2) reactor development and operation, principally related to the Advanced Test Reactor and associated programs in materials testing, isotope production, irradiation services, and other training and test support; (3) waste management and waste technology development for the Low-Level and Transuranic Waste programs; (4) nuclear safety research; (5) service and support for other laboratories which have major facilities at the site; and (6) other energy research programs and support to the Department of Defense and the Nuclear Regulatory Commission.

LAWRENCE BERKELEY LABORATORY MISSION STATEMENT

The primary mission of Lawrence Berkeley Laboratory is to develop and utilize major research complexes centered around large experimental facilities, to carry out fundamental research in high energy and nuclear physics and in materials sciences, and to conduct applied research and development in energy technologies. Lawrence Berkeley provides facilities to qualified investigators, and capitalizes on its co-location with the University of California to maintain close interaction with scientific personnel in universities and industry, and to train scientists and engineers.

To fulfill its mission, Lawrence Berkeley focuses its scientific and technical efforts on: (1) nuclear physics, focused on heavy-ion investigations and complementary programs in light-ion nuclear science; (2) high energy physics, with emphasis on broad investigations in particle physics, and development of advanced detectors; (3) materials sciences, focused on basic research, and on basic and applied work at the Center for Advanced Materials; (4) magnetic fusion, in the area of neutral beam plasma heating technology; (5) basic research in physical and life sciences, with emphasis on carcinogenesis and mutagenesis studies, and on a wide spectrum of chemical sciences including actinide chemistry and chemical energy and chemical engineering thermodynamics; (6) medical research, with emphasis on the medical uses of accelerated heavy ions; and (7) conservation and renewable energy, principally in the buildings and transportation sectors.

LAWRENCE LIVERMORE NATIONAL LABORATORY MISSION STATEMENT

The mission of the Lawrence Livermore National Laboratory is to be a national resource of scientific, technical, and engineering capability, especially concerning national security. It undertakes those multidisciplinary fundamental and applied research and development activities necessary to maintain a leading position in the broad range of scientific and technical fields required for this mission, and maintains close interaction with scientific and technical personnel in universities and industry.

Specific major programs include: (1) the research, development, and test activities associated with the nuclear design aspects of all phases of the nuclear weapon life cycle, and associated national security related tasks; (2) inertial confinement fusion, especially the short wavelength driver approach, aimed initially at weapon physics understanding and eventually civil power; (3) magnetic mirror fusion; (4) biological, ecological, and atmospheric aspects of energy and weapon technologies; (5) atomic vapor laser isotope separations; (6) other energy research programs; and (7) support to the U.S. intelligence community, the Department of Defense, the Nuclear Regulatory Commission, and other Federal agencies.

LOS ALAMOS NATIONAL LABORATORY MISSION STATEMENT

The primary mission of the Los Alamos National Laboratory is to be a national resource of scientific, technical and engineering capabilities focused on execution of its primary national security mission. It undertakes those multidisciplinary fundamental and applied research and development activities necessary to maintain a leading position in the broad range of scientific and technical fields required for this mission, and maintains close interaction with scientific personnel in universities and industry.

To fulfill its mission, it focuses its scientific and technical efforts on: (1) research, development and test activities associated with the nuclear design aspects of all phases of the nuclear weapon life cycle; (2) associated national security related tasks, particularly in strategic defense technologies, gas laser inertial fusion, intelligence analysis, verfication and control technology, molecular laser isotope separation, nuclear materials safeguards and security, and development of advanced nuclear and non-nuclear weapon concepts; (3) advanced magnetic fusion concepts; (4) nuclear physics; (5) high and medium energy physics, particularly in studies employing the Los Alamos Meson Physics Facility; (6) heavy ion fusion; (7) life sciences and environment; (8) basic energy sciences; (9) base technology for nuclear, fossil, renewable and geothermal energy; (10) conservation; (11) materials science; (12) modern chemistry; (13) chemical analysis; (14) lasers and photochemistry; (15) technology for control or isolation of nuclear, toxic or hazardous wastes; and (16) other energy research programs and support to the Department of Defense and the Nuclear Regulatory Commission and other federal agencies.

OAK RIDGE NATIONAL LABORATORY MISSION STATEMENT

The primary mission of Oak Ridge National Laboratory is to carry out applied research and engineering in fusion, fission and other energy technologies, and scientific research in basic physical and life sciences. Oak Ridge designs and provides research facilities for the benefit of members of the scientific and technical community, and maintains close interaction with scientific personnel in universities and industry. An important part of Oak Ridge's mission is the manufacture and sale of radioactive and stable isotopes that are not available from the private sector.

To fulfill its mission, Oak Ridge focuses its scientific and technical efforts on: (1) magnetic fusion, with emphasis on applied plasma physics, experimental and design studies of confinement configurations, development of plasma heating and fueling systems, development of prototype superconducting confinement magnets, and testing of candidate first wall and blanket materials; (2) nuclear fission, focused on development of nuclear fuel reprocessing, materials testing and development for high-temperature gas-cooled and breeder reactors, and technologies for managing nuclear waste; (3) biological and environmental research, with emphasis on interaction of energy-related physical and chemical agents with living organisms; (4) fossil energy, focused on development of materials for fossil fuel applications, and on health and environmental effects of coal conversion systems; (5) conservation and renewal energy, with emphasis on generic research for materials and technology development for buildings; and (6) basic research in physical sciences, with emphasis in materials research on radiation effects, neutron scatting and photovoltaic conversion, in chemical sciences on aqueous solutions, and in nuclear physics on heavy ion reactions.

PACIFIC NORTHWEST LABORATORY MISSION STATEMENT

The primary mission of Pacific Northwest National Laboratory is to carry out applied research and engineering for special nuclear materials production, nuclear waste management, and energy technology development. Pacific Northwest capitalizes on its co-location with Battelle facilities to maintain close interaction with scientific and technical personnel in the private sector.

To fulfill its mission, Pacific Northwest focuses its scientific and technical efforts on: (1) nuclear waste management, with emphasis on monitored retrievable storage, commercial spent fuel, and waste treatment technologies; (2) nuclear materials production, with emphasis on technical support of the Hanford production complex; (3) nuclear reactor safety, focused on human safety analysis, environmental impact assessment, fuel performance, and biological effects of nuclear and non-nuclear emissions; and (4) energy technology development, with emphasis on solar conversion and energy storage.

SANDIA NATIONAL LABORATORIES MISSION STATEMENT

The primary mission of Sandia National Laboratories is to be a national resource of scientific, technical and engineering capabilities focused on execution of its primary national security mission. It undertakes those multidisciplinary fundamental and applied research and development activities necessary to maintain a leading position in the broad range of scientific and technical fields required for this mission, and maintains close interaction with scientific personnel in universities and industry.

To fulfill its mission, it focuses its scientific and technical efforts on: (1) research and development associated with weapon engineering for all phases of the nuclear weapon life cycle; (2) associated national security related tasks, particularly in nuclear materials safeguards and security, inertial confinement fusion, verification and control technology, defense waste management and development of advanced concepts, such as the Strategic Defense Initiative; (3) conservation and renewable energy, focused largely on solar energy; (4) nuclear energy, principally in waste management and reactor safety; (5) fossil energy, including combustion of fossil fuels and geotechnology research; (6) fusion energy, mainly in plasma/material interactions; and (7) other research and development programs in support of the Department of Defense and the Nuclear Regulatory Commission.

DOE/ER-0179
UC-2

Guide to Energy R&D Programs for Universities & Other Research Groups

June 1984

U.S. Department of Energy
Office of Energy Research
Washington, D.C. 20585

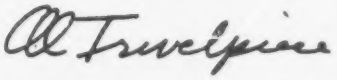
Foreword

The goal of national energy policy is to foster an adequate supply of energy at reasonable costs. The strategies for achieving this goal include the development and promotion of a balanced, mixed and diverse energy resource system. This balance and diversity is encouraged through the support of research and development by both the Government and private industry on new and alternative energy technologies to help ensure adequate future supplies of energy.

The Department of Energy (DOE) is the Federal Agency responsible for carrying out a comprehensive and balanced national energy program. A major part of this responsibility is the support of advanced scientific and technical research. This research serves two essential purposes. First, it advances the frontiers of scientific and engineering knowledge which, in turn, provides the underlying basis for future technological innovation. Second, it supports the development of new and alternative energy resources by providing the necessary scientific and technical basis for further development and ultimate commercialization by private industry. Within this context, DOE is specifically responsible for supporting basic research in the energy-related physical, life and environmental sciences; applied and proof-of-concept research in energy technology areas where the incentives for and the availability of private investment are severely limited or nonexistent; promoting energy conservation; carrying out essential nuclear defense-related activities; administering energy regulatory programs; collecting and analyzing energy information and data; and supporting fundamental research in the energy-related sciences.

Performers of DOE-sponsored research and development include industrial companies, Federal laboratories, universities and colleges. Participation by universities and colleges in the Department's energy research and development programs is particularly essential in that it constitutes a necessary national investment not only in advanced research, but also in the preparation and training of the next generation of the Nation's scientists and engineers. Universities are also a crucial link in the transfer of scientific and technical knowledge on energy to other users both in Government and in industry. Recognizing this, the Department is particularly interested in encouraging and supporting cooperative efforts in research and related manpower development involving universities, industry and the Federal laboratories.

We believe this guide will be of significant assistance to researchers in determining whether or not their research interests meet the needs and requirements of the Department of Energy. We would be most interested in comments and suggestions on how this guide may be improved as a resource for the scientific and technical community interested in DOE-sponsored programs.



Alvin W. Trivelpiece
Director, Office of
Energy Research

Table of Contents

Preface 5

Part I. DOE Research and Development Programs 7

A. DOE Budget Obligations by Type of Procurement-FY 1984 8

B. Office of Energy Research 13
University Research Support 13
Basic Energy Sciences 15
Health and Environmental Research 20
High Energy Physics 23
Magnetic Fusion Energy 24
Nuclear Physics 25
Program Analysis 26
Small Business Innovation Research Program 26
Program Dedicated Facilities 28

C. Fossil Energy 31
Advanced Process Technology 32
Advanced Research and Technology Development 32
Coal Liquefaction 33
Combustion Systems 33
Control Technology and Coal Preparation ... 33
Enhanced Oil Recovery 34
Fuel Cells (Including Thermionics) 35
Heat Engines 35
Magnetohydrodynamics 35
Oil Shale 36
Surface Coal Gasification 36
Unconventional Gas Recovery 37
Program Dedicated Facilities 38

D. Conservation and Renewable Energy 41

- Conservation Programs 42
  - Building Energy Research and Development 42
  - Energy Conversion and Utilization Technologies 43
  - Electric Energy Systems 44
  - Energy from Municipal Waste 44
  - Energy Storage Systems 44
  - Industrial Programs 45
  - Vehicle and Engine R&D 46
- Renewable Energy Programs 46
  - Active Heating and Cooling 46
  - Biomass Energy Technology 47
  - Geothermal and Hydroelectric Energy Technologies 47
  - Ocean Energy Technology 47
  - Passive and Hybrid Solar 48
  - Photovoltaic Energy Technology 48
  - Solar Thermal Energy Technology 49
  - Wind Energy Technology 49

E. Nuclear Energy 51
Advanced Nuclear Systems 52
Converter Reactor Systems 53
Liquid Metal Fast Breeder Reactor 54
Nuclear Fuel Cycle 54
Nuclear Waste Technology 54
Remedial Actions 55
Uranium Enrichment Activities 55
Water Cooled Breeder 55
Program Dedicated Facilities 56

F. Defense Programs 59
Defense Waste and Byproducts Management 60
Inertial Fusion 60
Military Applications 61
Nuclear Materials Production 61
Safeguards and Security 61

G. Office of Civilian Radioactive Waste Management 63
Geologic Repository Deployment 63
Storage and Systems Development 64

H. Energy Information Administration 64

I. Office of Minority Economic Impact 65

J. Office of Small Business and Disadvantaged Business Utilization 67

Part II. Operations Offices 69

Part III. Field Laboratories 73

A. Multiprogram Laboratories 73

B. Energy Technology Centers 77

C. DOE Sponsored Consortia 78

Part IV. DOE Procurement and Assistance Policies/Procedures 81
Competitive Solicitations 81
Unsolicited Proposals 82
Proposal Review and Evaluation 83
Types of Award Instruments 84
Patents, Data and Copyrights 84
Classification Research and Security Considerations 85
Reports 85
Audits 85
Glossary 86
References and Bibliography 87

Appendix 88

livestock, and forest production has shifted from the Northeast to other regions. The Northeast Regional Council submitted 10 priorities to the Joint Council, headed by basic research and scientific expertise development. Profitability in agriculture and farm financial and business management were the top two priorities of the Northeast Region Extension Directors.

North Central Region

More than 40 percent of the Nation's farm cash receipts are generated in this region. The region is an important producer of red meat, dairy products, food and feed grains, and oilseed crops. Major issues affecting this region are decline in farm profitability, soil erosion, competition for land use and resources, and export and commodity prices. The North Central Extension Directors placed farm financial and business management as their top priority, followed by profitability in agriculture. The North Central Agricultural Research Committee ranked biotechnology as the highest priority, followed by agricultural profitability.

Southern Region

Southern producers, like those in other U.S. regions, are faced with markedly lower profits. Soil erosion is a problem, and there is an urgent need to increase efficiency by focusing on plant and animal production systems. The Southern Regional Council submitted 13 priorities. The first was improved water management and water use efficiency; and second was improved animal health and reproduction. Extension Directors in the Southern Region gave profitability in agriculture and farm financial and business management their first and second rankings. The Southern Regional Research Committee placed the greatest emphasis on biotechnology, followed by soil and water management.

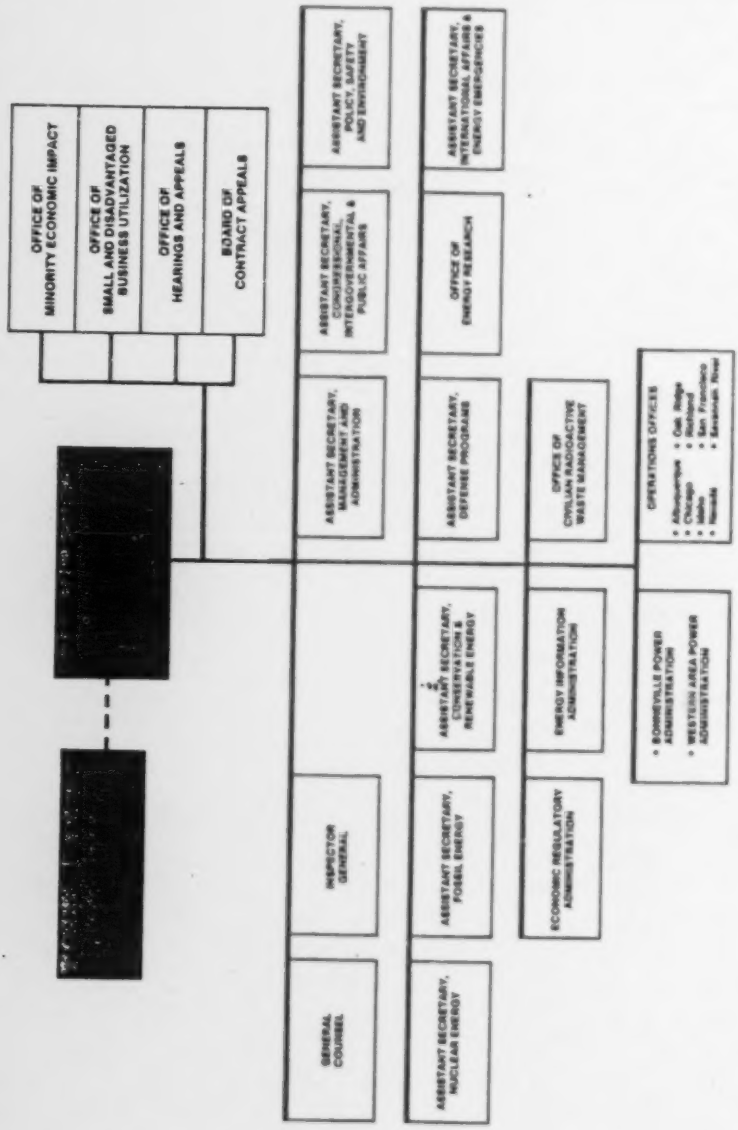
Western Region

The states in the Western Region have very diverse climates, topography, and agricultural commodity production. Water is a key to the West's economy. The Western Regional Council submitted 11 priorities for consideration by the Joint Council. Improving the use and conservation of water was the top priority of this Council, followed by product and market development. The Western Directors of Extension ranked agricultural profitability as their most urgent priority, followed by farm financial and business management.

Selecting the Top Priorities

After the Joint Council received the priority lists, the staff combined items covering similar areas. The consolidated list was first ranked in order of priority by Joint Council members individually. Subsequently, the Council met to discuss the proposals and select the five highest priorities for FY 1987.

The Department of Energy


OFFICE OF MINORITY ECONOMIC IMPACT
OFFICE OF SMALL AND DISADVANTAGED BUSINESS UTILIZATION
OFFICE OF HEARINGS AND APPEALS
BOARD OF CONTRACT APPEALS
ASSISTANT SECRETARY, POLICY, SAFETY AND ENVIRONMENT
ASSISTANT SECRETARY, CONGRESSIONAL, INTERGOVERNMENTAL & PUBLIC AFFAIRS
ASSISTANT SECRETARY, INTERNATIONAL AFFAIRS & ENERGY EMERGENCIES
ASSISTANT SECRETARY, MANAGEMENT AND ADMINISTRATION
OFFICE OF ENERGY RESEARCH
ASSISTANT SECRETARY, DEFENSE PROGRAMS
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
OPERATIONS OFFICES
• Albuquerque • Oak Ridge
• Chicago • Richland
• Idaho • San Francisco
• Nevada • Savannah River
ASSISTANT SECRETARY, CONSERVATION & RENEWABLE ENERGY
ENERGY INFORMATION ADMINISTRATION
• BONNEVILLE POWER ADMINISTRATION
• WESTERN AREA POWER ADMINISTRATION
GENERAL COUNSEL
INSPECTOR GENERAL
ASSISTANT SECRETARY, FOSSIL ENERGY
ECONOMIC REGULATORY ADMINISTRATION
ASSISTANT SECRETARY, NUCLEAR ENERGY

Part I.
DOE Research and Development Programs

Introduction

The Department of Energy performs several roles in support of the overall national energy effort. These roles may be summarized as follows:

- Develop fundamental scientific and engineering knowledge related to long-range energy R&D needs.
- Carry out energy-related applied research and technology development programs in specific areas that involve large, unpredictable and long-term costs or payoffs and, therefore, attract little or no private sector funding.
- Manage programs and facilities for national defense in the areas of nuclear weapons, nuclear materials and naval reactors.
- Stimulate the development and utilization of a wide range of energy options including conservation and renewable and conventional resources.
- Develop and manage energy emergency preparedness policies and programs.

DOE Organization

The organization of the Department of Energy includes a central headquarters staff located in both Washington, D.C., and in Germantown, Maryland, and an extensive network of program dedicated facilities and laboratories. Responsibilities of the DOE Headquarters include overall program management, planning, scheduling, budgeting, resource allocation and maintaining close working relationships with other Federal agencies and the Congress. The current organizational structure of the Department is shown in the chart on the preceding page. Most of the major energy research and development programs are administered by program staff located in the central Headquarters organization; however, there are several more applied research programs that are managed by staff in the program field offices and facilities. The reader is advised to check the "Proposal Review Procedures" section at the beginning of each major program area discussion for guidance on this matter.
formal proposals. Some program offices use in-house staff to review proposals while others may extensively use scientists at DOE laboratories and field facilities. Some programs use special advisory committees and panels to review proposals; others will exclusively rely on external mail review of proposals. The program staff contacts listed in each section of the guide should be consulted on the procedures followed in reviewing proposals in each program. The interested researcher seeking preproposal guidance on research needs and opportunities should also recognize that, while the ultimate program management responsibility always rests with DOE headquarters, some of the day-to-day implementation decisions may be delegated to a DOE field facility. In such instances, effort should be made to identify and communicate with the appropriate project manager in the field.

Principal Staff Officers

The Secretary of Energy is the chief executive officer of the Department. The Secretary's principal staff consists of a Deputy Secretary, an Under Secretary, a General Counsel, an Assistant Secretary for Management and Administration, the Director of the Office of Energy Research, and Program Assistant Secretaries and Administrators responsible for oversight and management of major Departmental programs.

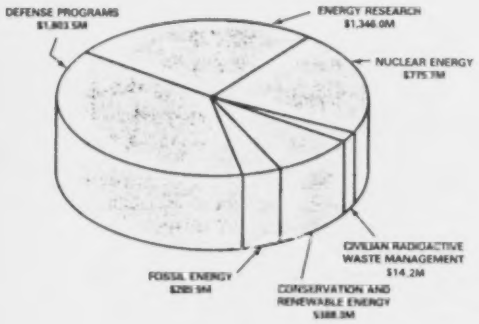
Information regarding the proposal review procedures used by each major program area is either included at the beginning of each program area discussion or is given in greater detail in the individual project description. It should be noted that there are differences among the DOE programs in the handling and review of preliminary and

Program objectives are cited for each technical program included in the guide together with a listing of problem areas requiring additional research and potential areas for new research initiatives. Summary budget data are provided to show the portion of funds for total research and development for a particular program area. The portion of the total program budget allocated for the support of research and development in universities is shown in Table I of the "DOE Budget Obligations" section.

A general point of contact is listed along with program-specific contacts to provide additional information. Telephone numbers for the points of contact listed in this guide may change from time to time. *Current DOE headquarters telephone numbers may be obtained by dialing the DOE locator; (202) 252-5000.*

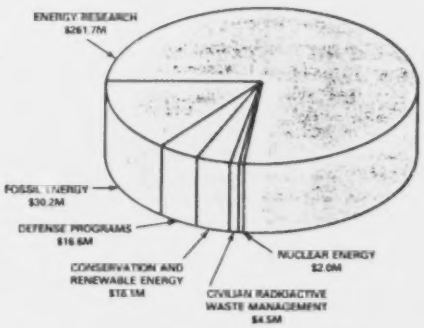
DOE Budget Obligations by Type of Procurement-FY 1984

TOTAL R&D BUDGET FOR FY 1984
($ IN MILLIONS)



TOTAL: $4,613.6 MILLION

DOE UNIVERSITY R&D FOR FY 1984
($ IN MILLIONS)



TOTAL: $331.1 MILLION

Budget Considerations

The figures above illustrate the total DOE R&D budget and highlight the estimated proportion of the budget being provided to universities for research and development initiatives. During FY 1983, an estimated $40 million was provided by the DOE National Laboratories on a subcontract basis for university research and development projects. In addition to this direct funding of university research by DOE programs, over $200 million of indirect support was provided to university faculty and students in FY 1983 through the Department's National Laboratories. (This total includes an estimate of the portion the operating costs of Laboratory research facilities when they are "used" by university scientists.)

A breakdown of funds for university research and development (direct awards only) by major program area is shown in Table I. The reader should be reminded, however, that these dollar figures are estimates only, and are subject to Congressional and programmatic changes which may occur at any time during the fiscal year.

Research Needs and Opportunities

The following section is devoted to a brief description of the major outlay programs of the Department of Energy and those technical programs included under each. These major areas are:

- Energy Research
- Conservation and Renewable Energy
- Defense Programs
- Fossil Energy
- Nuclear Energy
- Nuclear Waste Management (Commercial)

Other programs within the Department are not discussed in these descriptions because they support little, if any, R&D.

Also included are descriptions of DOE programs of special interest to the research community, including: the Energy Information Administration, the Office of Minority and Economic Impact, and the Office of Small and Disadvantaged Business Utilization. To assist the reader in determining field activity relationships, each major area discussed includes a brief section entitled "Field Elements."

Major R&D Programs

The major DOE research and technology development programs are organized under four Program Assistant Secretaries for Conservation and Renewable Energy (including solar and geothermal energy R&D), Fossil Energy, Nuclear Energy, Defense Programs, the Director for Civilian Radioactive Waste Management, and the Director of the Office of Energy Research (who is responsible for longer-range energy research, including general science related research). The Office of Energy Research has a major responsibility for the support of research involving universities.

The following pages include descriptions of each of the major R&D program areas in the Department and the Department's extensive national network of facilities and laboratories. It should be emphasized that many of these facilities and laboratories carry out research and related programs of direct benefit and assistance to university faculty and students including, but certainly not limited to, the operation of unique major research facilities and instruments such as high energy particle accelerators and synchroton radiation light sources. A summary of the major DOE field and laboratory network may be found in Parts II and III of this Guide.

Photo courtesy of Stanford University

445-150 0 - 84 - 2

Table 1

Summary of DOE Support for University Research and Development[1]

PROGRAMS	FY 1983 BUDGET AUTH. (ACTUAL) ($S IN MILLIONS)		FY 1984 BUDGET AUTH. (ESTIMATE) ($S IN MILLIONS)		FY1985 BUDGET AUTH. (PRESIDENTIAL REQ.) ($S IN MILLIONS)	
	UNIVERSITY R&D SUPPORT	% DOE TOTAL	UNIVERSITY R&D SUPPORT	% DOE TOTAL	UNIVERSITY R&D SUPPORT	% DOE TOTAL
OFFICE OF ENERGY RESEARCH						
UNIVERSITY RESEARCH SUPPORT	2.2		6.3		10.1	
BASIC ENERGY SCIENCES	68.2		73.1		85.3	
HEALTH & ENVIRONMENTAL RESEARCH	45.3		40.6		39.7	
HIGH ENERGY PHYSICS	57.7		62.6		70.0	
MAGNETIC FUSION ENERGY	45.2		44.5		45.3	
NUCLEAR PHYSICS	28.7		34.3		38.3	
PROGRAM ANALYSIS	.2		.3		.2	
TOTAL:	247.5	.76	261.7	.79	288.9	.85
OFFICE OF CONSERVATION & RENEWABLE ENERGY						
Conservation Programs						
BUILDING ENERGY R&D	1.9		1.9		1.2	
ENERGY CONVERSION & UTILIZATION TECH.	.0		.0		.0	
ELECTRIC ENERGY SYSTEMS	2.1		1.0		3.0	
ENERGY FROM MUNICIPAL WASTE	.3		.5		1.3	
ENERGY STORAGE SYSTEMS	2.0		2.0		1.2	
INDUSTRIAL PROGRAMS	4.0		.5		.3	
VEHICLE AND ENGINE R&D	.7		.4		.2	
SUBTOTAL:	11.0		6.3		7.2	
Renewable Energy Programs						
ACTIVE HEATING & COOLING	1.0		.8		.1[3]	
BIOMASS ENERGY TECHNOLOGY	1.6		.8		.1	
GEOTHERMAL & HYDROELECTRIC ENERGY TECH.	3.5		1.5		2.0	
OCEAN ENERGY TECHNOLOGY	.3		.0		.0	
PASSIVE & HYBRID SOLAR	.4		.0		.0[3]	
PHOTOVOLTAIC ENERGY TECHNOLOGY	10.5		4.9		.4	
SOLAR THERMAL ENERGY TECHNOLOGY	1.3		.8		.1	
WIND ENERGY	1.8		1.0		.1	
SUBTOTAL:	20.4		9.8		2.8	
TOTAL:	31.4	.10	16.1	.05	10.0	.03
OFFICE OF DEFENSE PROGRAMS						
DEFENSE WASTE & BYPRODUCTS MANAGEMENT	3.7		3.8		3.8	
INERTIAL FUSION	11.9		10.9		6.7	
MILITARY APPLICATION	1.3		1.4		2.2	
NUCLEAR MATERIALS PRODUCTION	.5		.5		.5	
SAFEGUARDS AND SECURITY	.0		.0		.0	
TOTAL:	17.4	.05	16.6	.05	13.2	.04

OFFICE OF FOSSIL ENERGY						
ADVANCED PROCESS TECHNOLOGY	.5		.8		.8	
ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT	6.1		9.8		10.7[4]	
COAL LIQUEFACTION	.1		.3		.2	
COMBUSTION SYSTEMS	.7		.6		.9	
CONTROL TECHNOLOGY & COAL PREPARATION	3.6		4.0		1.5	
ENHANCED OIL RECOVERY	2.7		2.1		2.0	
FUEL CELLS (INCLUDING THERMIONICS)	.1		.1		.0[4]	
HEAT ENGINES	.2		.3		.2	
MAGNETOHYDRODYNAMICS	8.3		8.5		2.5	
OIL SHALE	.6		.5		.3	
SURFACE COAL GASIFICATION	1.2		1.8		1.3	
UNCONVENTIONAL GAS RECOVERY/ UNDERGROUND COAL GASIFICATION	.4		1.4		.8	
TOTAL:	24.5	.07	30.2	.09	21.0[5]	.06
OFFICE OF NUCLEAR ENERGY						
ADVANCED NUCLEAR SYSTEMS	.0		.0		.0	
CONVERTER REACTOR SYSTEMS	1.6		.0		.0	
LIQUID METAL FAST BREEDER REACTOR	.1		.0		.0	
NUCLEAR FUEL CYCLE	.1		.0		.0	
NUCLEAR WASTE TECHNOLOGY	.0		.0		.0	
REMEDIAL ACTIONS	.0		.0		.0	
URANIUM ENRICHMENT ACTIVITIES	.3		2.0		1.5	
WATER COOLED BREEDER	.0		.0		.0	
TOTAL:	2.1	.01	2.0	.01	1.5	.00
OFFICE OF CIVILIAN RADIOACTIVE WASTE MGMT.						
GEOLOGIC REPOSITORY DEPLOYMENT	3.0		4.0		5.0	
STORAGE AND SYSTEMS DEVELOPMENT	.3		.5		1.0	
TOTAL:	3.3	.01	4.5	.01	6.0	.00
DOE TOTAL:	362.2		331.1		340.6	

[1] These totals reflect only direct awards and do not include university subcontracts or the operation of user facilities by the National Laboratories.

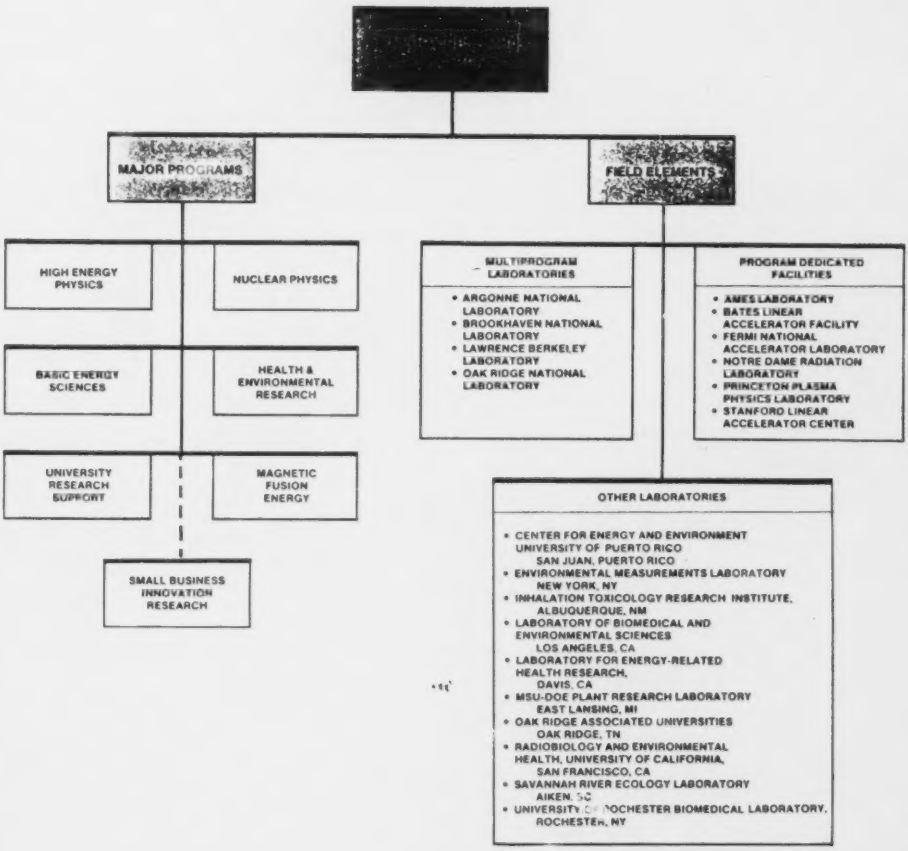
[2] Planning estimates only. Subject to change in Congressional Budget Review.

[3] For FY 1985, funding for the Active Heating and Cooling program and the Passive & Hybrid Solar program are combined as a single item.

[4] For FY 1985 the Advanced Research and Technology Development program and the Fuel Cells program are combined as a single item.

[5] The FE total does not include long-term agreements with the University of Wyoming and the University of North Dakota (approximately $19M in FY 1985).

Office of Energy Research


MAJOR PROGRAMS
FIELD ELEMENTS
HIGH ENERGY PHYSICS
NUCLEAR PHYSICS
BASIC ENERGY SCIENCES
HEALTH & ENVIRONMENTAL RESEARCH
UNIVERSITY RESEARCH SUPPORT
MAGNETIC FUSION ENERGY
SMALL BUSINESS INNOVATION RESEARCH
MULTIPROGRAM LABORATORIES
• ARGONNE NATIONAL LABORATORY
• BROOKHAVEN NATIONAL LABORATORY
• LAWRENCE BERKELEY LABORATORY
• OAK RIDGE NATIONAL LABORATORY
PROGRAM DEDICATED FACILITIES
• AMES LABORATORY
• BATES LINEAR ACCELERATOR FACILITY
• FERMI NATIONAL ACCELERATOR LABORATORY
• NOTRE DAME RADIATION LABORATORY
• PRINCETON PLASMA PHYSICS LABORATORY
• STANFORD LINEAR ACCELERATOR CENTER
OTHER LABORATORIES
• CENTER FOR ENERGY AND ENVIRONMENT UNIVERSITY OF PUERTO RICO SAN JUAN, PUERTO RICO
• ENVIRONMENTAL MEASUREMENTS LABORATORY NEW YORK, NY
• INHALATION TOXICOLOGY RESEARCH INSTITUTE, ALBUQUERQUE, NM
• LABORATORY OF BIOMEDICAL AND ENVIRONMENTAL SCIENCES LOS ANGELES, CA
• LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH, DAVIS, CA
• MSU-DOE PLANT RESEARCH LABORATORY EAST LANSING, MI
• OAK RIDGE ASSOCIATED UNIVERSITIES OAK RIDGE, TN
• RADIOBIOLOGY AND ENVIRONMENTAL HEALTH, UNIVERSITY OF CALIFORNIA, SAN FRANCISCO, CA
• SAVANNAH RIVER ECOLOGY LABORATORY AIKEN, SC
• UNIVERSITY OF ROCHESTER BIOMEDICAL LABORATORY, ROCHESTER, NY

Office of Energy Research

General Description

The Director of Energy Research is the principal advisor to the Secretary on DOE's physical research programs, the Department's overall energy research and development programs, environmental and health effects research, and university-based education/training activities. The Director also carries out additional duties assigned to the Office related to basic and advanced research, and the well-being and management of the non-weapons, major multiprogram laboratories under the jurisdiction of the Department.

The Office of Energy Research has also been assigned the administration and management responsibilities for the Small Business Innovation Research (SBIR) program of the Department. This is a new program developed to strengthen the role of small businesses in meeting Federal R&D needs and to stimulate technological/commercial innovation. Funds for the SBIR program are provided from all of DOE's major R&D program areas. A synopsis of the SBIR program and the other major programs of the Office of Energy Research is provided on the following pages.

Field Elements

Four multiprogram, six program dedicated facilities and eleven environmental laboratories are administratively assigned to the Office of Energy Research. Each of the four multiprogram laboratories (Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and the Lawrence Berkeley Laboratory) is briefly described in Part III of this guide. The program dedicated laboratories (the Ames Laboratory at Iowa State University, the Bates Linear Accelerator Facility at the Massachusetts Institute of Technology, the Fermi National Accelerator Laboratory, the Notre Dame Radiation Laboratory, the Princeton Plasma Physics Laboratory, and the Stanford Linear Accelerator Center) are summarized at the end of this Section. The multiprogram laboratories conduct significant research activities for other DOE programs and other Federal agencies, while the specialized and environmental laboratories are funded almost totally by a single program of the Office of Energy Research.

A summary of the proposal review procedures used by each research area within the Office of Energy Research is included in the individual project descriptions.

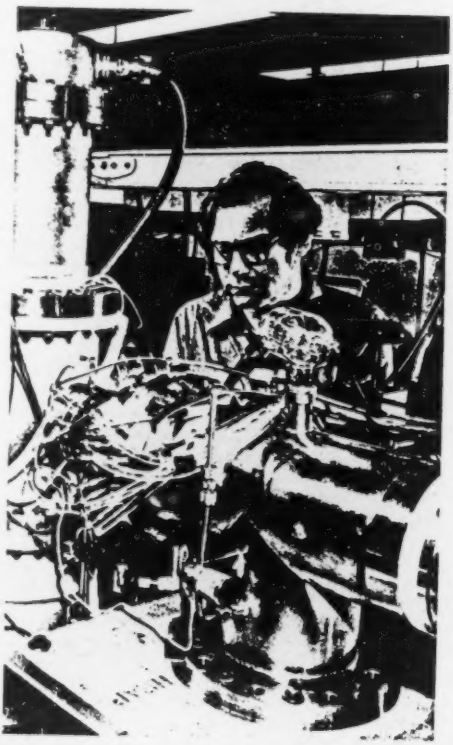
Program Information Contact

General Information

Richard E. Stephens (202) 252-8949

Reference

Secretary's Annual Report to Congress, September 1983 (DOE/S-0010(83)) (Energy Supporting Research Section)



University Research Support Program

Program Objective

The Division of University and Industry Programs in the Office of Energy Research performs two functions of particular interest to the university community.

The Division is responsible for the administration of a number of special university-oriented research and manpower development programs such as the Laboratory Cooperative Program and the assessment of projected manpower requirements for future energy research/technology development programs. The Division also carries out responsibilities designed to help strengthen and improve the Department's overall relationships with the academic community.

The university-related programs supported by this office are summarized as follows:

- The University Laboratory-Cooperative Program includes a variety of activities that bring college and university faculty and students to DOE Laboratories and Energy Technology Centers to participate in ongoing research programs and intensive instructional sessions on energy-related topics. These activities take full advantage of the unique and specialized facilities and research instrumentation at the Laboratories. Additional information on this program may be obtained by contacting staff members at participating DOE National Laboratories. (See Reference 1)
- The University Reactor Fuel Assistance Program provides financial support to colleges/universities to maintain nuclear research and training reactors, and to promote reactor sharing among colleges and universities.
- The University Research Instrumentation Program—The principal objective of this program is to provide financial assistance on a competitive basis to university research groups for the purchase of sophisticated, state-of-the-art research instrumentation required for advanced energy research. A program solicitation is prepared and released annually describing the specific objectives and areas of emphases for the program. Instrumentation eligible for support under this program will cost about $100,000 and above. This program is an integral part of the overall Federal effort designed to help reduce the shortage of major research instrumentation available to university scientists.
- The Energy Education and Training Program—This program provides support for a small number of pre-college oriented activities principally involving secondary school science teachers and students. Included in this overall program is the Pre-Freshman Engineering Program (PREP) which partially supports university-based engineering enrichment activities for minority and women secondary school students. The goal of the PREP program is to encourage minority and women students to pursue engineering careers following graduation from high school. Typical activities in a PREP project include science and mathematics remedial instruction, field trips to engineering-related industries, group and individual class projects, computer orientation and other problem solving tasks. Another related program activity supported by the Energy Education and Training Program involves scientists at various DOE national laboratories conducting short courses and institutes on energy-related science and engineering for secondary school science teachers and students in nearby school districts.
- Used Energy-Related Equipment Program—The purpose of this program is to provide university scientists and engineers with laboratory-related scientific instrumentation which has been declared surplus by DOE National Laboratories. This instrumentation (generally smaller instruments such as microscopes, oscillographs, etc.) is made available on a "first come-first serve" basis to universities for use in energy-oriented research or educational programs. Proposals requesting such surplus equipment should be submitted by the interested institution to the DOE Operations Office responsible for the site where the specific equipment to be surplused is located. Reference 2 provides further information on the policy and procedures for this program.

Staff in the Division also provide general assistance to university researchers and administrators interested in learning more about potential DOE energy research opportunities/needs and in establishing contact with appropriate Departmental program managers. Information and materials on DOE energy research and technology development programs are available from staff in the Division along with information on potential research and manpower development opportunities available to university faculty and students through the Department's various National Laboratories.

Proposal Review Procedures

Unsolicited proposals submitted to the Division of University and Industry Programs are reviewed by both Division staff and by external peer reviewers, as appropriate.

The PREP and University Research Instrumentation programs are competitive programs with annual solicitations. Proposals submitted in response to these solicitations will be evaluated by panels of experts in the appropriate scientific and technical areas.

Program Information Contacts

University Research/Instrumentation
Israel Warshaw (202) 252-1634
Education and Training Program
John Ortman (202) 252-1634
University Laboratory Cooperative Program
Harold H. Young (202) 252-6833
Used Equipment Program
Larry L. Barker (202) 252-6833
General Information/Assistance
Donna J. Prokop (202) 252-8910

References

1. Information Guide on University/Laboratory Cooperative Program, September 1983 (DOE/ER-0043/3)(Rev 83)
2. Instruction and Information on Used-Related Laboratory Equipment Grants for Educational Institutions of Higher Learning, March 1984 (DOE/ER-0042/2-Draft)
3. User's Guide to DOE Facilities, January 1984 (DOE/ER-0174)

Basic Energy Sciences

Program Objectives

The Office of Basic Energy Sciences (BES) is responsible for long-range basic energy-related research and is charged with providing the fundamental scientific foundation on which the nation's future energy options depend. Research is sponsored in selected areas of the traditional scientific disciplines—the physical and biological sciences, geosciences, engineering, and mathematics. Research projects are selected on the basis of scientific merit, the possible relevance to meeting BES long-range research goals, and the contribution toward a balanced, responsive research program.

The knowledge that results from BES-sponsored research becomes a part of the body of information on which the applied technologies rest. Although research to broaden the technology base needed for identified energy options is extremely important, even more important is the need for basic research unfettered by preconceived notions of what technologies will be important several decades from now so that new, not yet identified options may emerge.

While the Office of Basic Energy Sciences assigns priorities to specific areas based on a judgment of their importance to the Department's mission, the detailed substance of the program is determined by the selection from among many unsolicited proposals of ideas from the university/scientific community. Since basic research is usually carried out within the framework of the scientific disciplines, the program is structured and managed mostly along disciplinary lines.

There are seven subprograms:

- Materials Sciences
- Chemical Sciences
- Nuclear Sciences
- Engineering, Mathematical and Geosciences
- Advanced Energy
- Biological Energy Research
- Carbon Dioxide Research

The titles are descriptive, but do not convey the range of subject matter covered. For example, Chemical Sciences includes research in atomic and molecular physics, nearly all aspects of chemistry, chemical instrumentation, and some chemical engineering. Coverage by the other subprograms is similarly broad.

There are currently more than 1,200 research projects funded by Basic Energy Sciences. The following table provides the subprogram budget breakdown:

Each of the subprograms in Basic Energy Sciences has selected technical areas that are to be emphasized. It would be impractical to list them here in any detail. Those interested in these specific details should contact the individuals listed under "Program Information Contacts."

Proposal Review Procedures

Unsolicited research proposals are first screened by program officials, and if appropriate, are evaluated by peer review. Successful proposers are awarded one-year or multi-year special research contracts or grants with renewals or incremental funding available, provided performance has been satisfactory. Minimal technical reporting requirements are imposed, basically those needed for decisions as to renewal or termination. A one-to-two year phase out period is normally granted to those finishing research projects, in order to bring the work to an orderly conclusion and to support graduate students finishing their thesis research. All results are expected to be published in the appropriate scientific and technical journals.

Equipment items can be purchased from contract funds, with the agreement of program officials and the authorization of the contracting officer. The program also operates a number of unique facilities, usually located at the national laboratories, which are available to the user community. These include neutron scattering diffraction facilities, electron microscopes,and the Combustion Research Facility at the Sandia National Laboratory at Livermore, the National Synchrotron Light Source at Brookhaven National Laboratory, and the Stanford Synchrotron Radiation Laboratory. For a description of the facilities and their availability, please see Reference 1.

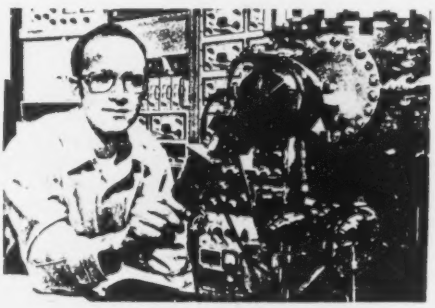
Materials Sciences

Research conducted under the Materials Sciences program is aimed at understanding materials properties and phenomena of importance to all energy systems. Materials often are the key limiting factor in the development of new systems, the performance of present systems, and the evolution of advanced concepts. In the Materials Sciences program, emphasis is placed on areas where problems are known to exist or are anticipated. Improved understanding of materials properties is sought in areas where significant improvements in performance and, therefore, economics depend on the selection of materials and design.

Some needs to which Materials Sciences research contributes include:

Budgetary Breakdown by Disciplinary Subprograms
(Operating Expenses)

	FY 1983 (Actual)	FY 1984 (Est.)
Materials Sciences	108.2	125.1
Chemical Sciences	70.0	75.5
Nuclear Sciences	30.6	37.9
Engineering, Mathematical and Geosciences	31.0	33.7
Advanced Energy Projects	8.3	9.1
Biological Energy Research	9.5	10.6
Carbon Dioxide Research	9.1	12.5



- Developing new or substitute materials;
- Tailoring materials to satisfy defined requirements;
- Predicting materials problems and service life;
- Improving the ability to successfully attack unforeseen materials problems in advanced energy systems; and
- Improving the theoretical and experimental capability to analyze the fundamental structure of materials.

BES's Materials Sciences subprogram provides about one-third of the total federal funding for basic materials research. Materials Sciences emphasizes selected generic areas of fundamental importance and areas where problems are known to exist or are anticipated. Some research is directed at a single energy technology (e.g., photovoltaic materials for solar energy conversion); some research has applicability to many technologies simultaneously (e.g., embrittlement of structural materials in the presence of hydrogen); and still other research has more fundamental implications underpinning all materials research (e.g., mechanisms of atomic transport in solids). The research is conducted in a variety of institutions—DOE laboratories, universities, and, to a lesser extent, industrial installations—and uses the talents of metallurgists, ceramicists, solid-state physicists, and materials chemists.

Chemical Sciences

Under the Chemical Sciences program, research is conducted in areas of chemistry, chemical engineering and atomic physics—both to provide a basis for the solution of current energy technology problems and to open new concepts for future development. The data and understanding that this program produces are of the kinds that can help make economically viable such newly developing energy technologies as coal liquefaction, or can help make possible other technologies such as fuel-making solar cells.

Phenomena and processes likely to be important to energy technologists are emphasized in the formulation of the program. Research in some areas, such as the chemical effects of catalysts, may lead to discoveries that can be quickly exploited by industrial process designers; whereas in other areas such as water-splitting photochemistry to produce hydrogen, research may not be used for a number of years. Still other research areas, such as studies of radiation emitted by ions moving very fast through crystal foils, produce data for use in developing new energy technologies.

The Chemical Sciences subprogram includes research in the fields of photochemistry, coal chemistry, catalysis, atomic physics of highly charged ions, chemistry basic to nuclear waste separation, biomass conversion, recovery of valuable metals from low-grade resources, efficient and clean combustion of various fuels, and detection and measurement of harmful by-products of energy processes. Equally important is the fundamental research into chemical and physical phenomena which has no immediately identifiable related technology. A typical example of such efforts is the study of laser-induced excited states of molecules. Disciplinary areas covered by Chemical Sciences work include physical, organic, and inorganic chemistry; chemical physics; radiation chemistry; thermodynamics; thermophysics; and analytical chemistry.

Nuclear Sciences

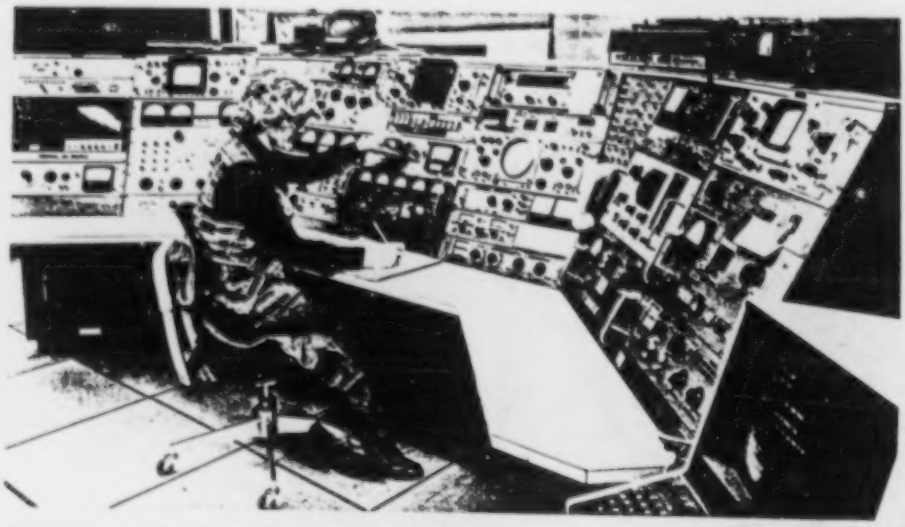
The Nuclear Sciences subprogram involves five distinct activities:

- Measure, compile, and evaluate nuclear data for fission and fusion energy technologies;
- Improve knowledge of the chemical and physical properties of the actinide elements;
- Assure the availability for research of isotopically enriched samples of the elements;
- Operate the Stanford Synchrotron Radiation Laboratory;
- Develop heavy ion accelerator technology (the Heavy Ion Fusion program).

The fission and fusion energy technologies require nuclear data for optimization of reactor design, analysis of operations and safety of reactor systems, and management of spent fuel materials. The nuclear data activity provides a broad base of data in support of these technologies.

The compilation and evaluation effort is concerned with establishing a data base for neutron-induced nuclear reactions and also with maintaining the Evaluated Nuclear Structure Data File (ENSDF), which encompasses all the information produced worldwide on the level structure and decay properties of nuclei. This effort is centered around the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory, which coordinates a network of scientists performing compilation and evaluation for ENSDF and also coordinates U.S. work with the International Atomic Energy Agency. Nuclear data measurement effort centers around the Oak Ridge Electron Linear Accelerator for measurement of neutron cross sections over a wide range of energies. Several small university groups and the National Bureau of Standards collaborate in these activities.

The nuclear energy and technology programs of DOE need specific information and data on the behavior of actinides in fuel processing streams, in nuclear waste hosts materials, and in the environment. Heavy element chemistry research helps meet their needs as well as contributing to an understanding of the fundamental chemical and physical properties and behavior of matter. These broadly based studies of the actinide elements include behavior in aqueous and nonaqueous solutions, photochemistry, chemical reactivity, spectroscopy, and chemical physics. The study of actinide chemistry is largely limited to the national laboratories since high



levels of radioactivity are involved, but some tracer work is done at universities. At the national laboratories, opportunities for visiting scientists from university and foreign labs to pursue collaborative research with the U.S. investigators are provided.

Nuclear Sciences also supports the electromagnetic separation of stable isotopes for a Research Materials Collection of samples that are loaned out for nondestructive research in DOE energy technology programs. In addition to its research and information-gathering activities, Nuclear Sciences is responsible for distributing the stable isotopes and the rare, heavy radioactive isotopes it produces for use in research, medicine, and industry. These efforts constitute the western world's only source of isotopic research samples in significant quantities, and these materials are sold or loaned to institutions throughout the world.

Responsibility for operating the Stanford Synchrotron Radiation Laboratory (SSRL) has recently been transferred to BES from the National Science Foundation. The SSRL, which shares the Stanford Positron Electron Asymmetric Ring with the high-energy physics program, is an important research facility. At present, it is heavily oversubscribed by the solid-state, chemical, and biomedical research communities for its high-intensity photons in the ultra-violet and X-ray regions of energy. This is one of two major BES facilities where research of this kind is made possible.

The Heavy Ion Fusion Accelerator Research (HIFAR) program is a new program under the energy activities within the Office of Energy Research. The program was previously supported by the Office of Inertial Fusion within Defense Programs. The goal of the HIFAR program is to develop heavy ion accelerator technology and perform appropriate ion beam experiments to the point where an adequate data base exists for evaluation of heavy ion inertial fusion drivers for use in civilian power applications. A program plan has been formulated based on the development of high current, multi-beam induction linacs to achieve the requisite peak beam power. Research includes advanced accelerator design, limits on beam current, beam focusing and stability, and preservation of required beam quality. Currently the effort is concentrated at the Lawrence Berkeley Laboratory and the Los Alamos National Laboratory.

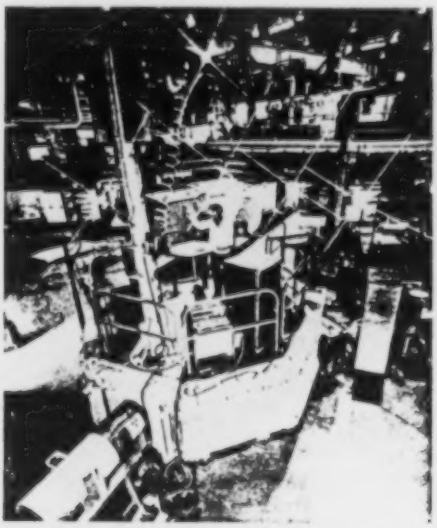
Engineering, Mathematical and Geosciences

The Engineering, Mathematical and Geosciences program funds fundamental research in a variety of disciplines important to meeting our Nation's energy needs. The program is carried out under three distinct activities: Engineering Research (mechanical, electrical and structural engineering), Applied Mathematical Sciences (mathematics, statistics and computer science), and Geosciences (geophysics geochemistry and geology).

The *Engineering Research Program* was initiated in 1979. The broad objectives of this program are to add to the store of fundamental knowledge for advancing energy-related engineering practices, to stimulate new engineering approaches to solving the Nation's energy problems, and to enhance the intellectual base for future energy-related engineering developments.

At present, three research areas are receiving high priority:

- Mechanical sciences-including tribology (the basic nature of friction-reduction phenomena), heat transfer, and solid mechanics (continuum mechanics and engineering aspects of crack propagation);
- Systems sciences-including process control, instrumentations, and scale-up of process plants;
- Engineering analysis-including nonlinear dynamics, thermophysical properties of fluids, and engineering combustion.



Engineering research also includes work on instrumentation for measuring basic engineering quantities—temperature, pressure, flow rates, and phase-under extreme conditions of temperature or pressure and efforts to model complex systems to develop predictive capabilities for the scale-up of pilot process plants.

The BES activity in *Applied Mathematical Sciences* supports approximately 200 mathematicians, statisticians, and computer scientists working on fundamental problems in the development of mathematical models of energy systems. The work is carried out at 30 universities and 10 national laboratories. In areas such as magnetic fusion, nuclear reactors, weapons design, and combustion processes, where experimental tests are difficult, expensive or even impossible, mathematical models provide the best methods of studying the underlying physical processes. The mathematics program emphasizes three aspects of the modeling process:

- Analytic and computational techniques for formulating and implementing models of energy systems from first principles;
- Statistical and computer science techniques for manipulating and analyzing large data bases associated with these models; and the
- Development of algorithms, languages, and architectures for future generations of computers that will be capable of solving more realistic models.

The most promising parallel computer architectures are being explored, concentrating on techniques for using hundreds or thousands of inexpensive microcomputers in parallel to solve complex systems of equations at rates ten to a hundred times faster than the best computer available today. A coordinated effort among university, national laboratory, and industry researchers is under way.

The nonlinear dynamics research promises to aid in understanding the nature of turbulence and chaotic motion, which governs reaction rates in combustion processes and plasmas, and coolant flow in reactors.

The objective of the *Geosciences* program is to develop a quantitative, predictive understanding of the energy-related aspects of geological, geophysical, and geochemical processes both in the earth and at the solar-terrestrial interface.

The Geosciences program is presently emphasizing (1) long-range research on the geological isolation of nuclear waste, (2) studies in organic geochemistry relating to fossil fuel recovery and the disposition of energy-related chemical waste, and (3) studies of the magma-hydrothermal part of the interagency Continental Scientific Drilling Program.

The effort in nuclear waste isolation addresses unresolved problems with second- and third-generation repositories, such as: migration of nuclear wastes; interactions among the waste container, rock, and fluids in the rock; and concentrations, diffusion rates, and element migration of nuclear wastes from a disposal site into its surroundings.

The organic geochemical processes of migration, physical changes, and maturation of fossil energy resources are also being studied. Such knowledge is essential if fossil fuels are to be effectively exploited and is required for dealing with the problems of organic wastes.

Advanced Energy Projects

The objective of the Advanced Energy Projects (AEP) subprogram is to explore the feasibility of novel energy-related concepts evolving from basic research which are at an early stage of scientific definition and, therefore, would not be of interest to technology programs. Advanced Energy Projects is an interdisciplinary program whose projects cover a broad technological spectrum. To qualify for AEP support, such concepts, even though they involve a high degree of risk, must have the potential for an eventual high payoff. Advanced Energy Projects also sponsors exploratory research on concepts that do not fit easily into the existing DOE program structure. An area of major attention is the transfer of successful projects to technology programs; a number of such transfers have already been made.

A relatively new BES subprogram, Advanced Energy Projects supports individual projects for a limited time only, with the goal of supporting about 20 new projects each year. It differs from other subprograms in that it does not fund ongoing, evolutionary research. After a period of concentrated effort, typically about 3 years, the concept is expected to have proved itself, and in which case the basic research phase is completed and the project can be transferred to a technology program. If a successful conclusion to the research is not foreseeable, the project is dropped. Projects are selected from unsolicited proposals received from researchers at universities, industrial laboratories (especially small R&D companies), and national laboratories. Currently, 36 projects are being supported; this allows a turnover rate of about 12 projects per year.

Biological Energy Research

The principal objective of Biological Energy Research is to provide basic information and conceptual

understanding in microbiological and botanical sciences for DOE's efforts in biomass production of fuels and chemicals, microbiological transformation of organic materials for conservation, and biological systems for resource recovery. The research is aimed at enhancing biomass productivity, converting biomass and other organic materials into fuel and chemicals by novel and improved methods of fermentation and developing biosystems capable of saving money.

The Biological Energy Research subprogram focuses on understanding the limits of biomass productivity in green plants, how plants adapt to suboptimal conditions of growth, such as those encountered in marginal lands and waters, and the mechanisms of microbial conversion of various biomass forms. In particular, the biochemical pathways of degradation of abundant materials such as cellulose, hemicelluloses, lignins, and the conversion of these materials to fuels or chemicals are studied.

Microorganisms that grow in the absence of oxygen and are able to carry out fermentation with high efficiency are of special interest, as are thermophillic microorganisms, which have optimal growth and conversion rates at high temperatures. An integral part of the subprogram information that may ultimately be used to produce new or improved microorganisms and plants to facilitate the production of fuels or petroleum-conserving chemicals or to yield biotechnologies capable of conserving energy.

This research into the physiology, biochemistry, and genetics of microorganisms and plants is carried out primarily at the universities.

Carbon Dioxide Research

The objective of the Carbon Dioxide Research subprogram is to improve scientific understanding of possible CO_2 sources and sinks, CO_2-induced climate modifications, and direct fertilization effects of CO_2 on vegetation. The global CO_2 content of the atmosphere has increased in recent history and continues to rise at a rate of about 1.5 parts per million per year. The effects of increased CO_2 in the atmosphere are uncertain. Scientists agree, however, that it can cause global climate changes involving temperature, precipitation, and wind circulation and that it may create a "fertilizer effect," which would increase crop yield and result in greater storage of fossil-fuel CO_2 by forests.

Carbon Dioxide Research aims to establish "knowns and unknowns," reduce and specify uncertainties, increase data collection, and improve measurements and models directed at answering specific questions about the sources and sinks of CO_2 climate, and other possible effects.

Much of the current research is focused on defining and measuring fluxes of CO_2 among major sources and sinks of the carbon cycle. Research efforts also include estimates of global and regional changes in temperature and precipitation aimed at identifying which climate changes result directly from the effects of CO_2 (as differentiated from the many other factors that could have been involved). General circulation models are being used to determine how an atmospheric CO_2-induced climate change may relate to the nonatmospheric components of the climate system, such as oceans, land, and the cryosphere. Preliminary results of studies with nonatmospheric-ocean models suggest that effects may be delayed a decade or more by the thermal inertia of the oceans. The photosynthesis, physiological, and water use of plants and trees are being studied to provide a basis for predicting the responses of vegetation to rising atmospheric CO_2.

Program Information Contacts

Mailing Address:
U.S. Department of Energy
Mail Station G-226
Washington, D.C. 20545

Materials Sciences	
L.C. Ianniello	(301) 353-3427
Chemical Sciences	
E.S. Pierce	(301) 353-5804
Nuclear Sciences	
E.T. Ritter	(301) 353-3613
Engineering, Mathematical and Geosciences	
J.S. Coleman	(301) 353-5822
Advanced Energy Projects	
R. Gajewski	(301) 353-5995
Biological Energy Research	
R. Rabson	(301) 353-2873
Carbon Dioxide Research	
F.A. Koomanoff	(301) 353-3281

References (Available on request)

1. 1982 Summary Report, Office of Basic Energy Sciences (DOE/ER-0146)
2. In addition, 200-word summaries of the research sponsored are available for:
- Materials Sciences (DOE/ER-0143/1)
- Chemical Sciences (DOE/ER-0144/1)
- Engineering (DOE/ER-0158/1)
- Geosciences (DOE/ER-0145/1)
- Carbon Dioxide (DOE/ER-0178)
- Applied Mathematical Sciences (DOE/ER-0157/1)
- Advanced Energy Projects (DOE/ER-0150/1)
- Biological Energy Research (DOE/ER-0147/1)

3. User's Guide to DOE Facilities, January 1984 (DOE/ER-0174)

Health and Environmental Research

Program Objective

The mission of the Office of Health and Environmental Research is to conduct an authoritative and comprehensive research program to identify, analyze and reduce those health and environmental uncertainties which could unnecessarily impede the safe and economical implementation of U.S. energy policy. A second mission is to conduct a research and development program on the applications of nuclear technology to the diagnosis and treatment of human disease.

This program is the only interdisciplinary research effort in the Federal government specifically devoted to the broad range of long-term energy-related health and environmental issues we are likely to face in expanding existing energy technologies or deploying new ones. The goal is to identify before a technology is locked into place, the long-term effects, if any, on human and environment health.

Research will be supported which will help identify and characterize potentially hazardous energy-related agents; understand their transport, conversion and fate in the environment; determine their ecological impact and pathways to humans; and define their potential effects on human health via direct observation and through studies with experimental animal, cellular and molecular systems. Research will also be supported to elucidate the structure, function and interrelationships of key components of living organisms in order to better understand the basis for susceptibility of critical life processes to energy-related agents. Medically useful applications for radioactive and stable isotopes, radiation beams and associated instrumentation will also be supported.

Health Effects Research

This program supports a coordinated research effort designed to yield experimental health effects data of the type needed to predict long-term health impacts that may be associated with developing energy technologies. A comprehensive experimental program of health research is necessary because of severe and unavoidable limitations that inevitably complicate the acquisition and interpretation of health data on human populations exposed to environmental agents.

The program is primarily concerned with evaluating the delayed types of health effects—tumors, heritable defects, developmental effects, and damage to body systems (organs)—that are caused by chronic low-level exposure to energy-related physical and chemical agents. The research utilizes molecular, cellular, and animal test systems to obtain quantitative data on dose-response relationships and to develop an understanding of species differences in sensitivity. Since credible extrapolation of such data to man requires a knowledge of mechanisms underlying the induction of adverse effects in different species and since the production of delayed effects is not clearly understood, extensive use is made of generic and basic research to provide experimental systems, techniques, and insights having the broadest application to health-risk prediction. Included is the development of improved biological test systems and improved techniques for the extrapolation of experimental data to man.

Health effects research cuts across virtually all of the energy technologies. Areas of ongoing research include those that address health effects associated with ionizing radiation, d-c magnetic fields, and a variety of energy-related chemicals including indoor air pollutants, polycyclic aromatic hydrocarbons and related compounds

associated with synfuel production. Extensive research is conducted to elucidate mechanisms of carcinogenesis, mutagenesis, metabolism of energy-related chemicals, and mechanisms of DNA repair. Categories or research opportunity include:

- Carcinogenesis—Both established and developing energy technologies produce or involve physical and/or chemical agents that can cause human cancer. Carcinogenesis research emphasizes evaluation of the tumorigenicity of such agents, detection and characterization of carcinogens, elucidation of pathways of carcinogen metabolism, development of sensitive chemical/biological indicators of turmorigenesis, investigations to correlate exposure conditions (carcinogen dose) with tumor incidence in animal populations, and elucidation of mechanisms of carcinogenesis. Because tumorigenesis is a complex process that may include discrete initiation and promotion steps, research on cancer induction often involves the study of complex interactions among different causative agents. Emphasis is also being given to research on the ultimate free radicals and other oxidizing species that play a role in both chemical and radiation carcinogenesis, and on body defense mechanisms against harmful oxidizing species.
- Mutagenesis—Alteration of genetic material by physical and chemical agents may produce heritable defects as a result of mutations in reproductive cells. Mutations in somatic cells and alteration of chromosome structure may result in cell modifications leading to cancer or other health effects. The mutagenesis research program emphasizes investigations of the mutagenic potential of energy-related physical and chemical agents; metabolism of chemical agents in target cells; correlation of mutation frequency with level of exposure to a mutagen; evaluation of health consequences that mutations may produce at the population level; measurement of DNA damage such as adduct formation; and elucidation of mechanisms of mutagenesis including the relationship of mutagenesis to tumor induction. Cytogenetic effects (chromosomal modifications) are also studied in detail as is the relationship of mutagenesis to cancer induction.
- Systems Damage—Many hazardous environmental agents manifest their toxic potential by imparing one of the body's functional systems. Such effects—particularly delayed impairment of the respiratory, immune, nervous, reproductive, and blood-forming systems or the developing embryo/fetal system—may lead to chronic disease with attendant health costs. The major efforts in this research area include the identification of early indicators of biological damage, interspecies comparison of major functional systems and their sensitivity to environmental agents, development of improved biological test systems, and conduct of dose-response studies that support risk estimates for man.
- General Life Sciences—This program is focused on long-term, basic research with the aim of providing the mechanistic and conceptual foundation that is needed to understand how physical and chemical agents interfere with life processes. Emphasis is directed to molecular and cellular studies that provide a basis for studying and understanding how environmental agents interact with key cell components to induce undesirable health effects. Included is research on *biophysics* (structure of macromolecules and organelles), *genetics* (including DNA damage and repair), and *cell biology* (cell growth, cell differentiation, cell regulation, and enzymology).

Human Health and Assessments

The Human Health and Assessment Division supports research to provide information on: the response of humans and human populations to toxicants and the feasibility of using nuclear technologies in medicine. The Division also supports analyses of the potential health and environmental consequences of emerging energy technologies.

- Human Health Research—This program is concerned with adverse effects on human health resulting from exposure to chemical, physical and biological factors associated with energy generation. To determine the nature and the extent of energy related health effects, research is conducted on populations and individuals that have been accidentally or occupationally exposed. Research in this program also includes the development of methods for the detection, prevention, and treatment of the effects of occupational or accidental exposure to hazardous agents associated with energy activities.
- Medical Applications of Nuclear Technology—In this program research is conducted on: improved methods of producing nuclides of medical interest; new radiopharmaceutical agents; improved instrumentation for measurement of nuclides; and clinical trials of promising new medical procedures using both stable and radioactive nuclides. Research is also conducted to determine the feasibility of using other nuclear technologies in medicine including: synchrotron light; neutron capture, heavy particle beams and shaped radio-frequency fields.
- Health and Environmental Risk Analysis Program—This program supports analyses to determine current uncertainty regarding the nature and magnitude of the potential health and environmental impacts of emerging energy technologies, the potential impacts of toxicants common to several technologies, and research to improve risk-analytic methodologies.

Physical and Technological Research

This subprogram is the physical sciences component of the Health and Environmental Research program. It addresses a broad range of fundamental and applied activities. Many of the projects are interactive with the biological and ecological components of the office. Other projects involve development of experimental techniques or advanced measurement instrumentation. The major areas addressed are: the physical and chemical characterization of products and effluents of new energy technologies; the transport and transformation of pollutants in the atmosphere, including climate/energy system interactions; measurement science; health and safety; and, the fundamental mechanisms of pollutant interaction with environmental and biological systems. Categories of research opportunity include:

- Analytical Characterization—The distribution, concentration and the physical, chemical and radiological properties of emissions and effluents

associated with energy-technology processes are determined. Included are field sampling/measurement and laboratory studies to provide detailed information on the chemical and physical properties of collected materials.

- Atmospheric Transport and Transformation—This category includes research to develop an improved understanding of meteorological, chemical, and physical processes that influence the transport, transformation, and fate of gaseous and particulate species emitted into the atmosphere. Improved atmospheric dispersion models are developed and validated through field experimentation. Climate research improves techniques to forecast climate impacts on energy systems.
- Measurement Science—New concepts and improved measurement systems required to address environmental, health, and safety concerns related to energy production are investigated. Research covers a broad scope of activities ranging from the basic-science of measurements to construction and evaluation of prototype instrumentation systems.
- Health Protection and Safety Research—New and improved methods, techniques, and procedures for industrial hygiene and radiation health-protection applications are developed. Research activities cover development of personnel contamination assessment techniques, as well as new approaches for determination of exposure to chemical and radiation pollutants.
- Mechanisms of Pollutant Interactions—Research into the fundamental mechanisms by which physical and chemical pollutants interact with biological and environmental systems is pursued. This includes studies of mechanisms by which atmospheric pollutants react witheach other and with natural environmental constituents; and the mechanisms by which the energy of radiation is converted into chemical species that are biologically active. Studies are experimental and theoretical, with computational modeling support.

Ecological Research

The ecological research program provides the environmental information needed to satisfy energy-use demands in a cost-effective, environmentally safe manner for appropriate siting, operation, and disposal of materials from energy activities. To obtain this information base, comprehensive research in terrestrial and aquatic systems is conducted in different climatic regions of the United States and in offshore regions along the eastern and western United States on mechanisms which control and influence total ecosystems. The research is carried out by integrating all aspects of the physical and biological sciences. This multidisciplinary program covers fields of soil science, plant science, animal biology, chemistry, geology and freshwater/marine sciences.

Research includes defining the transport and transformation of energy byproducts in terrestrial and marine systems, and identifying the major routes and rates of transfer of these byproducts through physical and biological pathways to human exposure. Natural and energy-related stresses are studied from the subcellular level to the community level of ecosystems to determine the rate and mechanisms by which populations and ecosystems disturbed by energy activities adapt or react to these stresses. Categories of research opportunity include:

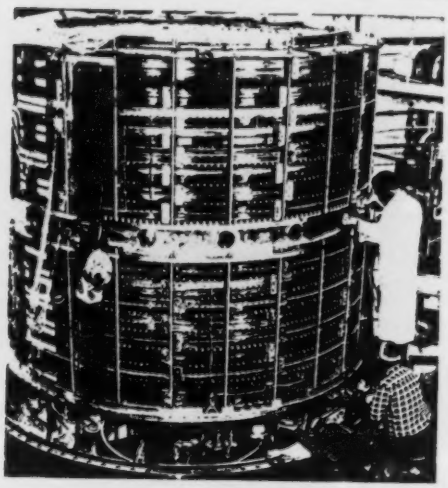
- Cycling of natural and energy materials which includes mobilization and movement of trace elements and compounds though water bodies, soils, sediments, plants and animals. Research on cycling of energy introduced substances is coupled to research on cycling of normally required nutrients to permit most appropriate cost effective measures to be developed for redistribution and control of energy material in the environment.
- Biologic responses derived from community structure, population dynamics and physiological ecology research. Knowledge on accommodation by plants and animals to natural stresses is used to allow energy-related activity to expand while taking into consideration limits of stress of the ecosystem. Natural successional processes are studied to determine if disturbed land is best left to natural revegetation or whether through habitat manipulation rehabilitation can be speeded up or enhanced. Research is carried out on metabolic processes which accumulate exposure levels that will allow ecosystems to exist without serious adverse impacts.
- Theoretical and statistical research to develop innovative theoretical approaches and sound statistical techniques that are applicable to ecological research in terrestrial, freshwater and marine environments.

Proposal Review Procedures

Unsolicited research proposals should be preceded by an informal preproposal that briefly describes the research project and the proposed level of funding. This need not exceed two or three pages. Preproposals are reviewed by OHER staff scientists to determine whether the proposed project falls within OHER's area of concern, and is of sufficient importance to justify preparation of a formal proposal. Generally a decision for this stage is made within a few weeks. If a formal submission is warranted, a copy of the pamphlet DOE/MA-0095 "Guide for the Submission of Unsolicited Proposals" will be provided.

The formal research proposal, after initial screening, is assigned to the appropriate OHER program division and a staff scientist designated to develop the formal evaluation and recommendation for action. All formal submissions are subjected to external peer review, generally involving three or more experts from the scientific community. The proposal and external reviews are then evaluated by a team of four or five technical staff drawn from the OHER professional staff of more than 30 scientists covering a diversity of biomedical and environmental disciplines. With the completion of this review step, the designated technical representative presents a summary of this proposal to the OHER Research Committee, (consisting of the technical staff from all program areas) for discussion and a formal recommendation for to the Associate Director for Health and Environmental Research for approval or rejection.

In selecting projects for support, OHER emphasizes its scientific merit (as it relates to energy or proposes to contribute knowledge to the field), the background and experience of the principal investigator, and the available facilities for the proposed work. Initiation of a contract from proposals found acceptable depends on the availablity



of funds and the importance of the proposed work in relation to other approved studies awaiting funding.

A period of three to six months may elapse before the proposal review is complete and a decision is reached by OHER. Receipt of the proposal will be acknowledged, and the applicant will be notified when a decision is reached with respect to the proposed work. If the proposal is approved, the applicant will be advised that, subject to the availability of funds, negotiation of an agreement or contract will be carried out by the designated DOE field office. DOE assumes no financial obligation until an agreement or contract has been executed.

Program Information Contacts

Health Effects Research	
M.L. Minthorn	(301) 353-5468
Human Health and Assessment	
N.F. Barr	(301) 353-5355
Physical and Technological Research	
R.W. Wood	(301) 353-3213
Ecological Research	
H. McCammon	(301) 353-4208
General Information	
M. Schulman	(301) 353-3338

References

1. Health and Environmental Research Program Related to Coal Conversion Technologies and Their Future Directions, December 1982 (CONF-820160)
2. Health and Environmental Research: Summary of Accomplishments, May 1983
3. A Plan for the Biological and Environmental Research Program: FY 1985-1990, September 1983
4. Research in Progress: FY 1984 (Summaries of Projects Sponsored by the Office of Health and Environmental Research), November 1983

High Energy Physics

Program Structure

The High Energy Physics Program is a basic research program which develops new fundamental knowledge and advanced technology of great value to energy programs. Its primary motivation is to understand the fundamental nature of matter and energy and the basic forces that govern their transformations. DOE provides about 90 percent of the Federal support, with the National Science Foundation providing the remainder. The central goal of these efforts is to achieve a comprehensive theoretical and experimental understanding of the fundamental constituents of matter and energy, the basic forces that govern their interactions, and the transformation of matter and energy in the most elemental level.

University research groups perform approximately 75 percent of the experiments scheduled at the three DOE high energy accelerators—Brookhaven National Laboratory, Fermi National Accelerator Laboratory, and Stanford Linear Accelerator Center. These laboratories are managed by universities or consortia of universities to provide unique and complementary capabilities in colliding beam facilities and fixed target accelerator systems which are vital to the frontier research program in high energy physics. University research, whether experimental or theoretical, is usually jointly funded by DOE and the home institution. For further information regarding laboratory facilities, see Reference 1.

Program Objectives

- Identify the ultimate constituents and structure of matter and energy;
- Understand the basic forces in nature which govern all interactions of matter and energy;
- Seek and discover new physical phenomena using high energy subnuclear particle interactions;
- Pursue advanced concepts and technology development;
- Maintain the United States program in a world leadership position; and
- Be alert to opportunities for the transfer of new technology developments and breakthroughs in high energy physics to energy development programs.

Long Range Planning for High Energy Physics

A typical experiment in high energy physics requires three-to-five years from design of apparatus to publication of results, while construction of a new accelerator facility usually consumes eight-to-ten years from conception to first beam operation. In cooperation with the High Energy Physics Advisory Panel and the National Science Foundation, the DOE High Energy Physics Program frequently updates its long-term strategy and plans for fulfilling the future needs of a strong and innovative research base. Strategy considerations include: the construction of specific new accelerator facilities as required for advances in research; effective operation of existing facilities; maintaining a strong university base; advanced technology development; funding for outstanding junior investigators; effective budget stability; and international collaboration for selected endeavors. The role of university scientists in determining and implementing long-range goals is important and pivotal

to all aspects of the program. The Outstanding Junior Investigator Awards have enabled creative young tenure-track scientists at the universities to launch independent research projects. Through the combined efforts of DOE program directors, advisory committees, special panels, university research offices and consultant contracts, colleges and universities have participated directly in DOE's attempts to seek the highest level of competence available for research requiring unique skills and expertise.

Proposal Review Procedures

Unsolicited proposals from universities to DOE for research support are analyzed by the High Energy Physics Program staff and undergo external peer review on an individual basis. Occasionally, competing proposals are also reviewed by special ad-hoc panels. Independently, experimental research proposals are submitted to national accelerator laboratories for review by a laboratory program advisory committee consisting of a panel of university and laboratory experts from across the nation. The program advisory committee advises the laboratory management on the scientific priority and merit of proposed research. The final decision to make accelerator facilities available for a particular experiment rests with the laboratory management. Successful research proposals for DOE support usually receive one-year contracts with provisions for review and renewal on an annual basis. Research results are expected to be published in appropriate journals. In addition to contributions of university research groups in forefront basic investigations, the universities provide fertile training grounds for the influx of new talent, which is essential to maintain the greatest vitality and creativity of the High Energy Physics program.

Program Information Contact

High Energy Physics
W.A. Wallenmeyer (301) 353-3624

References

1. User's Guide to DOE Facilities (DOE/ER-0174)
2. Summaries of Research in High Energy Physics (DOE/ER-0014)
3. High Energy Physicists and Graduate Students, Census (DOE/ER-0019)
4. High Energy Physics—The Ultimate Structure of Matter (DOE/ER-0027)

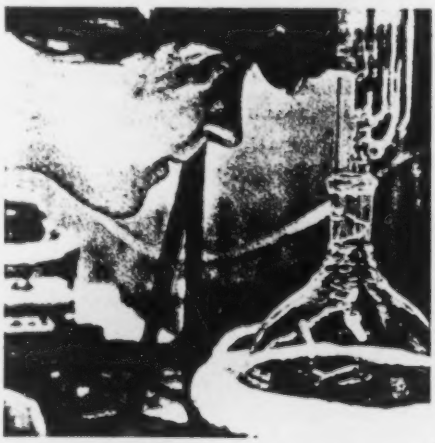
Magnetic Fusion Energy

Program Objectives

The DOE Fusion program consists of two activities—the unclassified magnetic fusion energy program, which is assigned to the Office of Energy Research, and discussed here, and the partially classified laser fusion program cited under Defense Programs.

The primary goal of the Magnetic Fusion Program is to develop the technology for safe, economic and environmentally acceptable use of fusion power for the generation of electricity. A secondary goal is to develop and evaluate other applications of the fusion process, including: the production of fissile material, synthetic fuels and industrial process heat. To achieve these goals, the program has established several objectives which are:

- To develop, through definitive experimental tests of key physics questions, the strong scientific base necessary for the design of a fusion engineering test facility;
- To complete the construction and initiate the operation of major physics scaling experiments including the Tokamak Fusion Test Reactor and the Mirror Fusion Test Facility;
- To select tests and provide an assessment of alternative fusion concepts that could potentially lead to more economical and commercially practical fusion reactor systems;
- To provide the base engineering and technology developments needed to support the operation of current and next generation plasma experiments;
- To complete reactor studies of the most promising confinement concepts in order to provide a focus for the physics and technology programs; and
- To establish a strong technology base in materials, reactor components and systems which will permit an evaluation of various approaches to fusion on the basis of technology requirements, economic objectives and environment/safety constraints.



Problem Areas Requiring Additional Research

- Physics of plasma heating and confinement;
- Plasma diagnostics;
- Atomic physics of plasma impurities;
- Improved materials for fusion applications; and
- Radiation materials damage.

Potential Areas for New Research Initiatives

- New fusion concepts and improvements to existing concepts;
- Plasma-surface interactions; and
- Modeling of engineering components.

Proposal Review Procedure
Solicited or unsolicited proposals are subjected to a technical peer review process. Acceptable proposals must provide for technical assessments of long-range, high-risk and high potential payoff research in energy technologies. Proposals for hardware development, development of models or algorithm tools, or experimental efforts, are not acceptable by the office. Proposals will be judged on the basis of their novelty, appropriateness to the Department of Energy's priorities, potential for useful data generation, expected quality of efforts, cost and availability of funds.

Program Information Contacts

Applied Plasma Physics	
D.B. Nelson	(301) 353-3287
Development and Technology	
R.J. Dowling	(301) 353-5378
Mirror Confinement Systems	
R.E. Price	(301) 353-2848
Toroidal Confinement Systems	
N.A. Davies	(301) 353-4095

Nuclear Physics

Program Objectives
The DOE Nuclear Physics Program is the major Federal research effort concerned with advanced experimental and theoretical studies of the interactions, structure, and other fundamental characteristics of atomic nuclei. Its four major components are: Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, Low Energy Nuclear Physics, and Nuclear Theory. Medium Energy, Heavy Ion, and Low Energy Nuclear Physics are experimental efforts heavily dependent upon the existence and the effective operation of major accelerator facilities. Seven of these accelerators are operated as national facilities, where beam time is made available to the Nation's scientists on the basis of scientific merit and technical feasibility of proposals submitted. The national facilities are: the Clinton P. Anderson Meson Physics Facility at the Los Alamos National Laboratory; the William H. Bates Linear Accelerator at the Massachusetts Institute of Technology; the SuperHILAC/Bevalac at the Lawrence Berkeley Laboratory; the 88-Inch Cyclotron at the Lawrence Berkeley Laboratory; the Tandem/Linac Facility at the Argonne National Laboratory; the Holifield Heavy Ion Research Facility at the Oak Ridge National Laboratory; and the Double MP tandem van de Graaff facility at the Brookhaven National Laboratory. Each of these national facilities, as well as smaller accelerators at the University of Washington, Duke University, Texas A&M University and Yale University, accommodates major university-based user group research programs.

Major Objectives
- To describe quantitatively the behavior and structure of complex nuclei in terms of fundamental interactions;
- To use nuclei as a laboratory for the study of fundamental forces in nature;
- To develop phenomenological understandings in those cases where the nuclear system is too complex to be treated in terms of fundamental forces;
- To advance research capability by developing new facilities, improving beams available to existing facilities and equipping experimental areas with advanced instrumentation;
- To identify practical applications resulting from nuclear research studies and to transfer the results to the appropriate scientific discipline or technology; and
- To maintain a position of leadership in nuclear research for the United States.

Long Range Planning for Nuclear Physics
In cooperation with the Department of Energy and the National Science Foundation, the DOE/NSF Nuclear Science Advisory Committee has developed a long-range national plan for basic nuclear research. The plan recognizes the central importance of accelerator facilities and related instrumentation. It specifically calls for a balanced mixture of new facility construction and upgrading of existing facilities in order that major scientific questions may be attacked with adequate tools and in order that America's position of leadership in nuclear research may be maintained. However, the plan also clearly recognizes that our greatest asset is the creativity and innovativeness of American scientists. The role of university-based scientists is of central importance to this endeavor; both for the intellectual and other resources they bring to bear on today's research programs and for providing a fertile training ground for creative and innovative scientists of the future.

Proposal Review Procedures
A typical user group plans experiments at the home institution, executes and partially analyzes experiments at the national facility, and completes the analyses and publication of results at the home institution. The DOE Nuclear Physics program is the major Federal supporter of such university-based user groups in the field of nuclear research. The Nuclear Theory effort is closely related to the experimental work in that it provides guidance to experiments along those lines most likely to yield a deeper and more unified understanding of nuclear phenomena, and it helps to interpret experimental results in terms of fundamental theory. Support of work under Nuclear Theory is almost equally divided between national laboratory-based theorists and university-based theorists.

Peer review is used extensively for proposals for: (1) direct funding of university-based scientists who wish to conduct experiments at the national facilities and (2) access to the accelerator installations.

Written proposals for direct funding should be sent to the Department of Energy. In almost all cases, Department staff request active peer scientists to provide written comments on the scientific merit of the proposed research, competence of the proposers to conduct the proposed research, and technical feasibility of the proposed research. These comments are treated as confidential and, upon request, are provided to the proposers without the reviewer's name or address. Decisions on whether or not to fund a specific proposal are based upon these peer review comments, internal Departmental staff review, examination of overall program priorities, and budgetary constraints.

Written proposals for access to the accelerator installations should be sent to the director of the facility

57-279 O - 87 - 48

at which experiments are to be conducted. The respective facility directors can be contacted directly for information on proposal format and timing. Although evaluation procedures vary somewhat from facility to facility, the general practice is to review the proposal by a panel of peer scientists called a Program Advisory Committee (PAC). Typically, PAC meetings are held twice a year at each facility. The scientists proposing experiments are asked to present their proposal orally before the PAC and to answer questions from the PAC. The PAC provides written recommendations to the facility director who then informs the proposer of the results of the proposal review. For further information regarding the location contact, and necessary arrangements for the DOE user facilities, please refer to Reference 2, below.

Program Information Contact
Nuclear Physics
E.T. Ritter (301) 353-3613

References (Available by request)
1. Program Information, Office of High Energy and Nuclear Physics, 1980.
2. User's Guide to DOE Facilities, January 1984 (DOE/ER-0174).

Office of Program Analysis

Program Objectives
The Office of Program Analysis (OPA) assists the Director, Office of Energy Research, by monitoring the Department's energy research and development programs in order to advise the Secretary regarding any undesirable duplications or gaps in such programs. Its major functions include: assessing the adequacy of the technology base supporting the research and development programs; performing independent analyses and technology assessments; and advising of alternative actions to support policy decisions.

OPA recently concluded an assessment of the accomplishments of the Office of Health and Environmental Research. An ongoing assessment of research needs in Fossil Energy is being conducted by the Coal Combustion Research Working Group. New assessments are being performed by outside contractors in solar thermal conversion, photovoltaics, geothermal, energy conversion and conservation, and nuclear waste management.

Potential Areas for New Research Initiatives
- Foreign Energy Technology Research Status and Directions
- Energy Technology Research Needs Dictated by Environmental or Health Constraints
- Research Needs Associated with the Disposal of Hazardous Wastes (Non-radioactive) from Energy Systems

Proposal Review Procedures
Solicited or unsolicited proposals are subjected to a technical peer review process. Acceptable proposals must provide for technical assessments of long-range, high-risk and high potential payoff research in energy technologies. Proposals for hardware development, development of models or algorithm tools, or experimental efforts, are not acceptable by the office. Proposals will be judged on the basis of their novelty, appropriateness to the Department of Energy's priorities, potential for useful data generation, expected quality of efforts, cost and availability of funds.

Program Information Contact
Program Analysis
George Y. Jordy (301) 353-2971

Small Business Innovation Research

Program Objectives
The Small Business Innovation Research (SBIR) Program is a new effort at the Department of Energy which was mandated by the Development Act of 1982 (P.L. 97-219) and is administered through the Office of Energy Research. The principal purposes of the SBIR Program are: (1) to stimulate technological innovation; (2) to use small business to meet Federal research and development needs; (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and (4) to increase private sector commercialization innovations derived from Federal research and development.

There are three phases to the SBIR program:

Phase I—Proposals are submitted in response to a SBIR program solicitation and are reviewed primarily on the basis of scientific/technical merit, feasibility of ideas, qualifications of the principal investigator, anticipated benefits, and the adequacy of the proposed effort to show progress toward providing feasibility of the concept. Emphasis will be placed on ideas that significantly contribute to energy-related scientific/engineering research or research and development. Approximately 100 awards were made in FY 1983 for Phase I of the SBIR program in amounts ranging up to $50,000 for a period of up to six months.

Phase II—The intent of Phase II is to further develop ideas explored under Phase I. Awards will be made to firms with approaches to problems that appear sufficiently promising under Phase I. It is anticipated that one-third to one-half of Phase I awardees will receive Phase II awards after an evaluation of Phase II proposals. Phase II awards are expected to range from $200,000 to $500,000, for a period of performance not to exceed 24 months.

Phase III—The intent of Phase III is for non-Federal capital interests to convert DOE sponsored efforts (under Phase I and Phase II) into technological innovation. Thus, DOE pays for the prerequisite feasibility and research efforts necessary for follow-on commercialization funding by non-Federal capital interests. Non-SBIR funded production contracts with a Federal agency for products or processes intended for use by the Government are another possibility under Phase III.

Phase I and Phase II awards will both continue in FY 1984 and FY 1985.

Potential Areas for New Research Initiatives

The Department of Energy issues SBIR Program Solicitations annually. There are 25 research areas included in the FY 1984 program solicitation which can be considered representative of topics to be seen in the future program solicitations. These are:

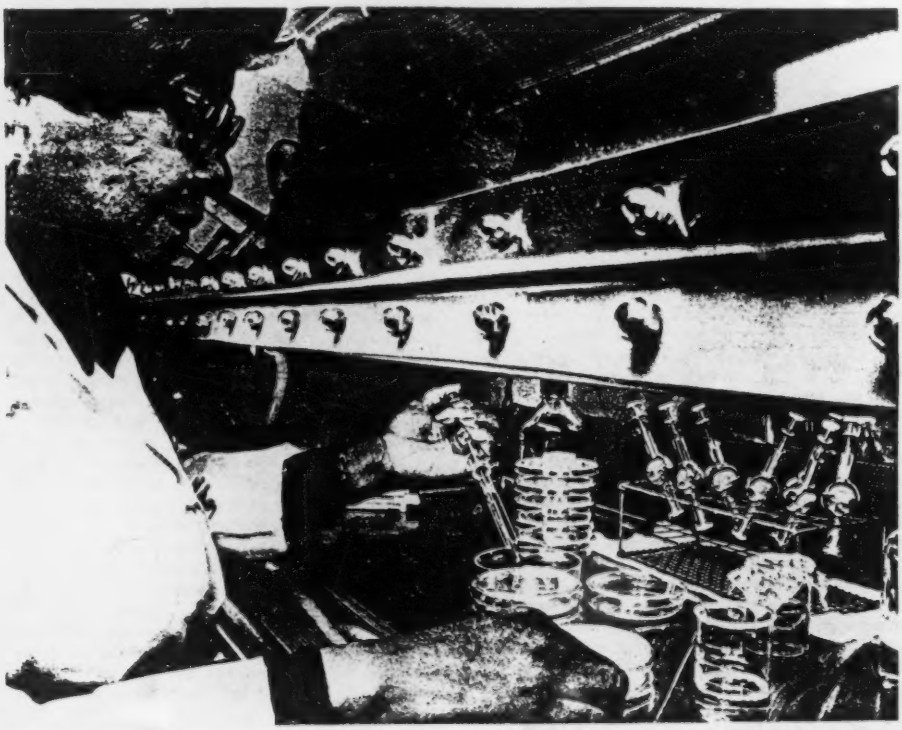
- Materials Science
- Chemical Separations
- Supercomputer Research
- Artificial Intelligence in Advanced Control Systems
- Biological Analyses
- Health and Environmental Effects Instrumentation
- Plasma Diagnostics
- Plasma Confinement Systems Technology
- Fusion Energy Systems
- High Energy Physics Technology and Research
- Particle Accelerator Technology
- Nuclear Physics Instrumentation and Technology
- Fossil Energy Power Generation
- Coal Utilization and Conversion
- Enhanced Oil Recovery and Tar Sands
- Fossil Energy Instrumentation
- Low-level Radioactive Waste Management
- High-level Radioactive Waste Handling and Treatment
- Nuclear Reactor Instrumentation and Technology
- Uranium Enrichment Technology
- Geothermal Technology
- Energy from Municipal Solid Waste
- Biomass Energy Research
- Electrochemistry and Batteries
- Photovoltaic Research

The FY 1984 solicitation was issued in January, 1984. Requests for the solicitation and questions pertaining to the solicitation should be addressed in writing to:

SBIR Program Office
U.S. Department of Energy
Washington, D.C. 20545

For reasons of competitive fairness, oral communications regarding the solicitation are restricted during the proposal preparation period. General questions about the DOE SBIR Program, but not pertaining to the solicitation or to requests for additional copies, can be submitted to the program information contact listed below.

Program Information Contact
Small Business Innovation Research
Geraldine Washington (301) 353-5867



Program Dedicated Facilities

Ames Laboratory
Iowa State University
Ames, Iowa 50011

Robert S. Hansen
Director
Telephone Number (515) 294-2770

Daniel E. Williams
General University Activities Contact
Telephone Number (515) 294-2635

Ames Laboratory is operated for DOE by Iowa State University under the administrative management of the Chicago Operations Office. The Laboratory conducts research principally in materials sciences centering on the preparation, purification, chemical characterization and structure identification of new materials, followed by evaluation and interpretation of their chemical, physical and mechanical properties. Smaller but unique and vigorous capabilities are maintained in nuclear physics, applied mathematics, coal preparation science, and non-destructive materials testing.

The Laboratory enjoys extensive cooperation with Iowa State University through year-round faculty appointment, graduate student training, and facilities sharing programs. A summer research participation program for undergraduate students and faculty members (primarily from non-local institutions) is also supported by the Laboratory.

Bates Linear Accelerator Facility
Massachusetts Institute of Technology
Post Office Box 95
Middletown, Massachusetts 01949

Irnest Moniz
Director
Telephone Number (617) 245-6600

The Bates Linear Accelerator Facility is operated for the Office of Energy Research by the Massachusetts Institute of Technology (MIT). The Bates installation includes a linear accelerator and recirculation system which provides electron beams with energy up to 750 MeV. The facility also includes magnetic spectrometer systems, detector systems, and computers essential to execution of basic nuclear research experiments. Experimental work at Bates is closely coordinated with a major theory program at MIT. The principal emphasis of the Bates program includes the following: (1) determination of electric charge, magnetic moment, and current distributions in nuclei by high resolution, high precision electron scattering experiments; (2) measurement of electromagnetic properties of nuclear states and nuclear deformation parameters by high-resolution, high precision electron scattering; (3) the investigation of the momentum distribution of nucleons bound within complex nuclei, (4) role of nucleon resonances in nuclear structure, and (5) fundamental pion production amplitudes by means of photon-induced reactions. The capability of the Bates Accelerator for basic studies of electromagnetic properties of nuclei is unique in the United States. Each year approximately forty universities and other institutions participate in basic nuclear research at the Bates facility.

Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Illinois 60510

Leon Lederman
Director
Telephone Number (312) 840-3211

Philip V. Livdahl
General University Activities Contact
Telephone Number (312) 840-3211

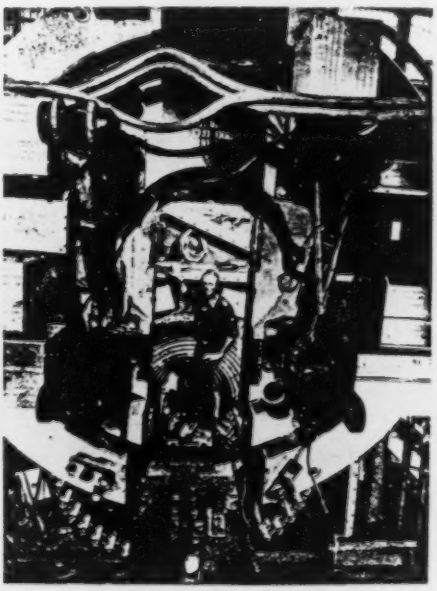
The Fermi National Accelerator Laboratory is operated for the Office of Energy Research by the Universities Research Association, Inc. (URA), a consortium of 54 universities throughout the United States and Canada. Its central purpose is to explore the field of elementary particle physics so that the understanding of the basic structure of matter may be broadened. Related to this purpose is the improvement of accelerator design, which has resulted in numerous technological spin-offs such as the development of various applications for superconductivity, in addition to using it for magnets, fast electronics and particle detector technology, and special computers/computer programs. Additionally, Fermilab's linear accelerator is used in cancer therapy; thus the laboratory has become deeply involved in a project outside high energy physics: a medical radiation therapy facility. The principal scientific instrument is a particle accelerator system, consisting of a series of five accelerators, capable of terminal energies up to 700 billion electron volts (GeV) at the present time. The Laboratory has several major construction projects underway (Energy Saver, Tevatron I and II) which will upgrade the accelerator's capability to 1,000 GeV for fixed target physics and construct a matter-antimatter colliding beams facility at an energy level of 2,000 GeV. This will significantly increase the Laboratory's capability to perform advanced particle physics research.

Notre Dame Radiation Laboratory
University of Notre Dame
Notre Dame, Indiana 46556

Robert H. Schuler
Director
Telephone Number (219) 239-7502

Dr. F. M. Kobayashi
General University Activities Contact
Telephone Number (219) 239-7378

The Notre Dame Radiation Laboratory is operated by Notre Dame University for the Office of Energy Research. Its objective is to study radiation effects—to obtain, through theoretical and experimental research, detailed descriptions of the mechanisms leading to chemical change following the absorption of high-energy radiation and light; and to construct predictive models that will be useful in experimental and technological applications where reactions are initiated by radiation chemical and photochemical methods. The laboratory maintains an outstanding complement of equipment such as linear and Van de Graaff accelerators, cobalt-60 gamma-ray sources, lasers and photochemical sources. Unique facilities include a coupled Van de Graaf-ESR spectrometer for studying radiation produced by visible and ultraviolet light, and computer-controlled apparatus for ready acquisition and processing of optical absorption data in pulse radiolysis and flash photolysis experiments. These facilities are made available to university and individual scientists for appropriate research.



Princeton Plasma Physics Laboratory
Princeton University
P.O. Box 451
Princeton, New Jersey 08544

Harold P. Furth
Director
Telephone Number (609) 683-3555

Robert G. Mills
General University Activities Contact
Telephone Number (609) 683-2469

The Princeton Plasma Physics Laboratory (PPPL), operated by Princeton University for the Office of Energy Research, is one of the major controlled thermonuclear research facilities supported by DOE. Its mission is to produce and control thermonuclear fusion for the purpose of developing an electrical energy source that would be economic, inexhaustible, and environmentally attractive. PPPL is able to conduct experimental, theoretical, and computer investigations into all branches of plasma physics. Currently, the low-density toroidal research at PPPL is leading the world effort in advanced heating methods, attainment of high electron and ion temperatures, and development of detailed diagnostics for high-temperature toroidal plasmas.

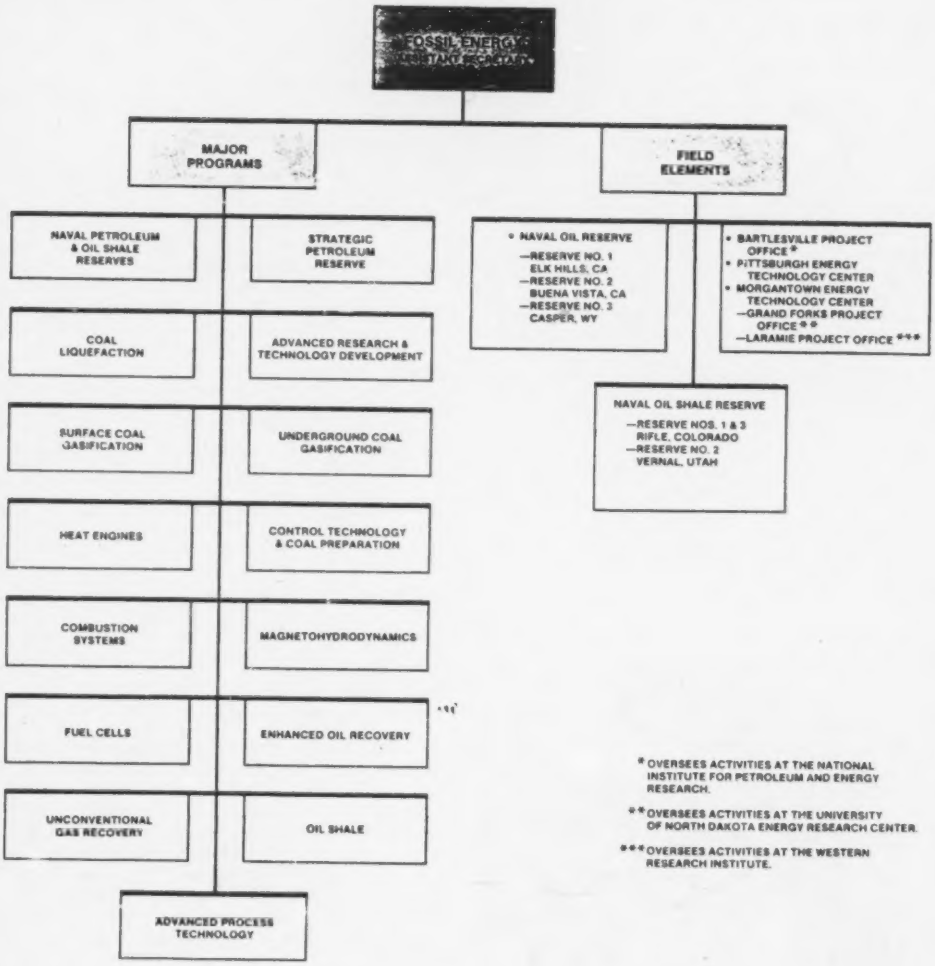
Stanford Linear Accelerator Center
P.O. Box 4349
Stanford, California 94305

Dr. W. K. H. Panofsky
Director
Telephone Number (415) 854-3300, X2601

Eugene B. Rickansrud
General University Activities Contact
Telephone Number (415) 854-3300, X2217

The Stanford Linear Accelerator Center is operated by Stanford University for the Office of Energy Research to carry out experimental and theoretical research in high-energy physics, to develop new techniques for particle acceleration and for experimental instrumentation. SLAC's main research instrument is a two mile-long linear electron accelerator, the largest of its kind in the world. This machine is augmented by two electron positron colliding beam storage rings: the 4.5 GeV per beam (9 GeV center of mass) SPEAR ring with two interaction regions; and the 18 GeV per beam (36 GeV center of mass) PEP storage ring with 6 interaction regions. These accelerators are complemented by an impressive array of large detectors including: a hybrid bubble chamber facility; a detector constructed of sodium iodide prisms; and a number of sophisticated magnetic spectrometers, each uniquely optimized for some specific aspect of particle physics detection. The array of detectors is supported by a central computer facility consisting of two IBM 370/168 and one IBM 3081 mainframe central processing units plus associated peripherals. Additionally, SPEAR supports the Stanford Synchrotron Radiation Laboratory which is an independent entity to exploit the synchrotron light emitted as a byproduct of the spear storage ring.

Fossil Energy


FOSSIL ENERGY
MAJOR PROGRAMS
FIELD ELEMENTS
NAVAL PETROLEUM & OIL SHALE RESERVES
STRATEGIC PETROLEUM RESERVE
COAL LIQUEFACTION
ADVANCED RESEARCH & TECHNOLOGY DEVELOPMENT
SURFACE COAL GASIFICATION
UNDERGROUND COAL GASIFICATION
HEAT ENGINES
CONTROL TECHNOLOGY & COAL PREPARATION
COMBUSTION SYSTEMS
MAGNETOHYDRODYNAMICS
FUEL CELLS
ENHANCED OIL RECOVERY
UNCONVENTIONAL GAS RECOVERY
OIL SHALE
ADVANCED PROCESS TECHNOLOGY
• NAVAL OIL RESERVE
—RESERVE NO. 1 ELK HILLS, CA
—RESERVE NO. 2 BUENA VISTA, CA
—RESERVE NO. 3 CASPER, WY
• BARTLESVILLE PROJECT OFFICE *
• PITTSBURGH ENERGY TECHNOLOGY CENTER
• MORGANTOWN ENERGY TECHNOLOGY CENTER
—GRAND FORKS PROJECT OFFICE **
—LARAMIE PROJECT OFFICE ***
NAVAL OIL SHALE RESERVE
—RESERVE NOS. 1 & 3 RIFLE, COLORADO
—RESERVE NO. 2 VERNAL, UTAH
* OVERSEES ACTIVITIES AT THE NATIONAL INSTITUTE FOR PETROLEUM AND ENERGY RESEARCH.
** OVERSEES ACTIVITIES AT THE UNIVERSITY OF NORTH DAKOTA ENERGY RESEARCH CENTER.
*** OVERSEES ACTIVITIES AT THE WESTERN RESEARCH INSTITUTE.

Assistant Secretary for Fossil Energy

General Description

The primary mission of the Fossil Energy (FE) program is to support longer-term, high-risk R&D with high potential payoff that will help increase domestic production of oil and gas or that will permit the nation to shift from the use of oil and gas to more abundant coal and oil shale resources. Near-term technical support for large scale process activities is limited to cases where the government has a unique resource or facility. The longer-range research activities in Fossil Energy focus on acquiring the technology base necessary for industry to develop and demonstrate hardware with minimal government involvement. Specifically, the Fossil Energy role is to support long-term research toward the following objectives:

- Provide an improved capability to convert coal and oil shale to liquid and gaseous fuels;
- Increase domestic production of coal, oil and gas;
- Ensure that current and new facilities that burn coal can do so in an economically viable and environmentally acceptable manner;
- Allow more efficient and more economically attractive utilization of fossil energy resources.

The Fossil Energy activity includes thirteen major programs, grouped under seven program offices and staff groups, which are discussed in the following pages. In addition, the Strategic Petroleum Reserve (SPR) and the Naval Petroleum and Oil Shale Reserves have been assigned to the office. One of these seven program offices is the Office of Technical Coordination, which is the central point of contact for inquiries from universities concerning the Fossil Energy Program.

Program execution is primarily carried out by two energy technology centers. These centers are described in Part III of this guide. Other associated program dedicated research institutions are discussed at the end of this section.

Proposal Review Procedures

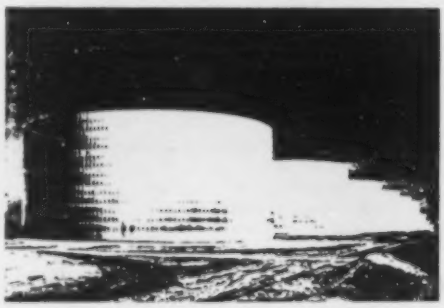
The general policy in Fossil Energy is to assure that there is a central uniform system that identifies, reviews and evaluates unsolicited proposals, preproposals, and revised or renewal proposals. These proposals may be submitted at any time or specifically in response to a solicitation. *The Pittsburgh Energy Technology Center (PETC) is responsible for all such proposals that pertain to any part of the Fossil Energy Program.*

All incoming unsolicited proposals received by FE, including letters of transmittal, will be transmitted to the:

Pittsburgh Energy Technology Center
Attn: Supervisor, Proposal Operations, OP-20
P. O. Box 10940
Pittsburgh, Pennsylvania 15236.

PETC will screen each proposal to determine if it pertains to the Fossil Energy Program. If the proposal does not pertain to the FE Program, PETC will either notify the sender by letter as to where and to whom the proposal should be sent, or they will forward the unsolicited proposal to DOE Headquarters for possible reassignment.

If the proposal does pertain to the FE Program, the proposal will be assigned a number, entered into a tracking log and sent to the most appropriate FE program office. This office will review the proposal and identify at least



two peer reviewers who do not directly work for DOE. PETC will arrange for an outside review and will forward the results to the FE program office for action. Notification of proposal acceptance or rejection is prepared by the proposal operations manager at PETC. If a preproposal has been submitted and the FE program office is interested in reviewing a full proposal, the sender will be so notified.

Somewhat more elaborate procedures are followed when proposals are submitted in response to a Program Solicitation (PS) for the University Coal Research program. Each proposal receives at least four independent peer reviews and are ranked in order of priority by the reviewers at an annual meeting held after individual reviews are complete. Ranking is primarily determined by the quality of the proposal. Top rated proposals receive research grants.

Program Information Contact
Office of Technical Coordination
Richard J. Bergemann (301) 353-2786

Advanced Process Technology

Program Objective
The Advanced Process Technology (APT) Program is an integral part of DOE's oil, gas, shale, tar sand, and coal liquids research programs. These research programs provide significant underpinning to DOE's emphasis on liquid fuels to satisfy national security and economic welfare strategic needs. The APT Program provides crosscutting advanced exploratory research support in extraction, processing, and utilization technologies that influence all fossil-derived liquid fuels. In addition, the APT Program includes Arctic/Offshore fundamental research projects that will aid the development of these promising oil and gas resource areas.

Potential Areas for New Research Initiatives

Advanced Exploratory Research
- Advanced Extraction Technology
  - — Laboratory studies (and small scale field tests) of the use of microbes to enhance oil recovery;
  - — Advanced extraction instrumentation development;
  - — Environmental impact mitigation research on subsidence and aquifer restoration.
- Fundamental Petroleum Chemistry
  - — Basic research into the physical, chemical, and thermodynamic properties of fossil-derived liquid fuels;
  - — Laboratory research into storage/handling stability problems in heavy crude and shale oil caused by heteroatom content; and
  - — Metals coordination chemistry research.
- Advanced Utilization Technology
  - — Analysis of fuel-sulfur and fuel-nitrogen effects on engine air emissions;
  - — Investigation of fuel hydrogen-to-carbon ratio on engine air emissions; and
  - — Basic engine combustion studies on emerging fossil-derived fuels.

Arctic/Offshore Research
- Ice Characterization
  - — Laboratory and field analysis of ice geometry and forces;
  - — Investigation of the migration and drift of ice islands; and
  - — Development of predictive ice analysis models.
- Seafloor/Soils Research
  - — Permafrost evaluations and mapping for Arctic regions;
  - — Investigation of ice-induced seafloor scouring and gouging phenomena; and
  - — Field application of the Seafloor Earthquake Measurement System (SEMS) to study seafloor stability in the arctic.

Program Information Contact
Advanced Process Technology
Gerald J. Parker (301) 353-3032

Advanced Research and Technology Development

Program Objective
The objectives of the Advanced Research and Technology Development program are to assess and identify long-range advanced research needs in coal processing, fossil fuels utilization and extraction, materials, components, and instrumentation; to provide oversight and technical assessments of ongoing advanced research in fossil energy so as to ensure balance and proper priorities; to initiate and fund projects involving new, exploratory concepts or goal-oriented basic research; to provide for university coal research; and to provide policies for, and overview of, Fossil Energy supported university activities. The Advanced Research and Technology Development program also is designed to provide an effective communications channel between the Fossil Energy program and academic institutions, and to encourage these institutions to become involved in programs related to the DOE Fossil Energy mission.

Areas Covered by Current Projects

Research

- Materials research;
- Coal science;
- Fluids and solids handling;
- Instrumentation and control;
- Component exploratory development;
- Technology transfer;
- Coal characterization and specificity related to liquefaction and gasification processes;
- The structure and reactions of coal and analysis of its conversion products;
- Multiphase flow and thermodynamic phenomena related to coal conversion processes;
- Fundamental problems in combustion of pulverized coal, synfuels and coal-liquid mixtures; and
- Environmental aspects directly related to coal conversion processes and coal utilization.

Program Information Contact
Advanced Research and Technology Development
Richard J. Bergemann (301) 353-2786

Coal Liquefaction

Program Objective
The objectives of the Coal Liquefaction program are to develop advanced technology for the production of liquid fuel from coal to support commercial activity in the private sector based on the following:

- Improved process technology to convert domestic coal into refinery feedstocks, distillate heating oil, gasoline, and chemical feedstocks; and
- Novel and innovative processes in laboratory bench scale units.

Areas Covered by Current Projects

Technology Development

- Coal liquefaction processes, e.g., solvent extraction, catalytic liquefaction, donor two-stage processes and indirect liquefaction;
- Improved components and instrumentation.

Research

- Liquefaction
  - — Extraction
    - — Hydroextraction/desulfurization process research;
  - — Catalytic hydroliquefaction
    - — Exploratory evaluation of catalysts;
    - — Investigation of improved reactor concepts
  - — Indirect Liquefaction (liquids from synthesis gas)
    - — Improve catalysts ;
    - — Improve reactor concepts
  - — Refining and Chemicals
    - — Exploratory refining processes;
    - — Refining of coal-derived synthetic crude oils; and
  - — Supporting Research
    - — Basic chemical and engineering studies, e.g., structure of coal, pre-asphaltenes, mechanism of coal hydroliquefaction, coal/solvent/hydrogen mixing studies, catalytic reactor modeling design studies, preheater studies, role of mineral matter in coal liquefaction.
    - — Environmental and health effects and their mitigation.

Program Information Contact
Coal Liquefaction
James Batchelor (301) 353-3482

Combustion Systems

Program Objective
The activities of this program emphasize furthering the development of technologies that would allow greater coal use; these are coal-based mixtures, atmospheric fluidized bed combustion, pressurized fluidized bed combustion, and novel combustion processes.

Areas Covered by Current Projects

Technology Development

- Atmospheric and fluidized bed combustions systems;
- Advanced Combustors.

Research

- Fluidized bed combustion;
- Coal combustion;
- Coal/water slurry development and combustion;
- Fluid dynamics in coal combustion systems.

Program Information Contact
Combustion Systems
Howard Feibus (301) 353-4348

Control Technology and Coal Preparation

Program Objective
The activities of this program emphasize furthering the development of technologies that will allow for greater utilization of coal in an environmentally acceptable manner. These include: coal characterization and cleaning for both direct utilization and for feedstock in coal conversion processes; combined flue gas cleanup process for single step control of boiler NO_x, SO_x, and particulate emissions; processes for cleanup of hot coal combustion and gasification streams in support of advanced coal utilization systems such as gas turbines and molten carbonate fuel cells, and management of wastes generated in coal conversion and utilization processes.

Areas Covered by Current Projects

Technology Development

- Chemical and physical coal deashing and desulfurization processes and techniques;
- Spray dryer based flue gas cleanup processes;
- Electron radiation catalyzed, simultaneous SO_2/NO_2 cleanup processes;
- Particulate and alkali cleanup of hot combustion and gasification streams;
- Instrumentation for real time, in situ measurement of contaminants partial PPM levels at elevated temperature and pressure;
- Coal preparation processes and techniques for more efficient removal of sulfur and ash, retention of coal fines and dewatering.

Research

- Pollutant formation and reaction chemistry;
- High temperature gas stream desulfurization;
- Ammonia decomposition catalysis at high temperature;
- Control techniques for organic compounds and trace metals at high temperature;
- Combustion modification for NO_x and particulate control;
- Waste disposal (Fixation/stabilization, soil attenuation, size monitoring);
- Technical and economic assessments;
- Evaluation and characterization of coal and coal waste properties;
- Innovative coal preparation concepts.

Program Information Contact
Control Technology and Coal Preparation
Howard Feibus (301) 353-4348

Enhanced Oil Recovery

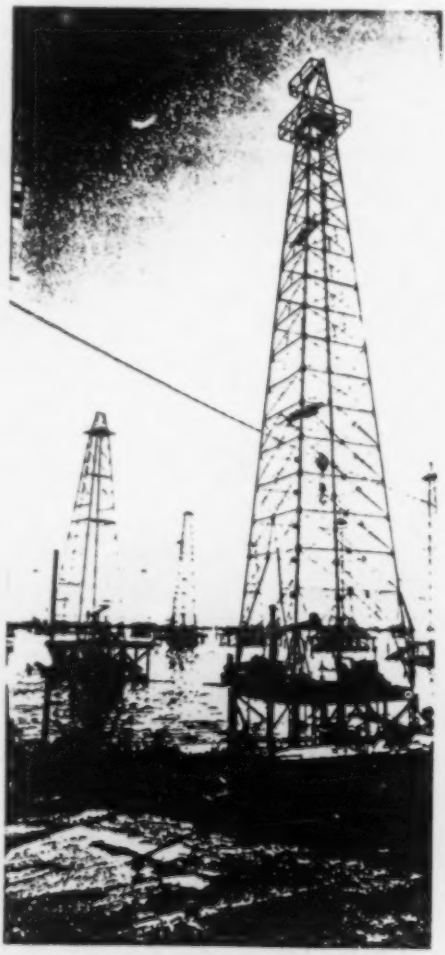
Program Objective

The objective of the Enhanced Oil Recovery (EOR) program is to conduct technology base R&D activities of the generic kind, to assist industry to obtain a better understanding of the mechanisms and behavior of advanced and novel EOR processes for light oil, heavy oil, and tar sand resources.

Because private industry can be expected to continue to improve upon existing EOR processes and to eventually develop new research areas in response to oil price increases, the EOR program now directs its primary emphasis on long- range, high-risk, technology base research with the main thrust on those elements that attract limited or no private venture capital, either because the risks are too high or the payoffs are too far in the future.

Potential Areas for New Research Initiatives

- Fundamental physical and chemical surface phenomena, when enhanced oil recovery (EOR) fluids are injected into petroleum reservoirs;
- Disposal of oil field brines containing EOR chemicals;
- Efficiency of crude oil recovery using gas such as N_2 or CO_2;



- Research on a process allowing mobility control to reduce gravity override and fingering in the recovery of heavy oil;
- Inorganic surfactants;
- Advanced/novel processes for EOR and tar sand extraction;
- Assess the effects of reservoir parameters such as temperature and wettability or relative permeability to oil and water.

Program Information Contact
Enhanced Oil Recovery
George Stosur (301) 353-2918

Fuel Cells (Including Thermionics)

Program Objective

Fuel cells are electrochemical devices which convert the chemical energy contained in the gases generated in hydrocarbon fuel combustion directly into electricity. The objective of the program is to develop fuel cell technology for electric utility and on-site electric power generation systems and for industrial cogeneration applications. Work on advanced fuel cell concepts includes the development of fuel cells for military and transportation applications, and for the direct conversion of coal.

Included in the fuel cell program, although not a fuel cell, is thermionic energy conversion. It is electrothermal. Carnot cycle technology wherein thermal energy of hydrocarbon fuel combustion (or solar, nuclear fission or fusion, or MHD exhaust heat) is converted directly into electricity. The objective of this program is to develop thermionics for topping gas turbine combustion chambers for combined cycle electric utility power generation and for industrial cogeneration applications.

A summary of the major areas being investigated follows:

- Phosphoric acid fuel cell systems:
  - — 4.8 megawatt electric utility powerplant;
  - — 40 kilowatt on-site, integrated power system.
- Molten carbonate fuel cell system:
  - — Coal gas fueled electric utility system;
  - — Industrial cogeneration systems.
- Solid oxide and advanced fuel concepts:
  - — Solid oxide electrolyte, high temperature fuel cell technology for electric utility, on-site and industrial cogeneration;
  - — Advanced fuel cell technology for military and transportation applications;
  - — Thermionic topping of combustion chamber of gas turbine combined cycle gasification powerplant.
- Industrial cogeneration applications using a thermionic burner;
- Technology base development.

Potential Areas for News Research Initiatives

- Surface catalysis;
- Fuel cell oxygen electrodes;
- Electrode and matrix materials development;
- Contamination tolerance;
- Theoretical and experimental plasma physics;
- High temperature, protective ceramic coatings development.

Research

- Relevant combustion phenomena
- Supporting fuel studies

Program Information Contact
Fuel Cells
George Rudins (301) 353-5910

Heat Engines

Program Objective

Research and development under this program is aimed towards coal-fueled gas turbine and diesel engine technologies. Users of these power systems face long-range uncertainties in the cost and availability of clean distillate and natural gas fuels upon which they normally depend. The program's principal purpose is to establish a firm technology base in combustion, thermal design, and supporting disciplines that would facilitate full scale commercial development by the private sector in the mid 1990's.

Areas Covered by Current Projects

Technology Development

- Combustor design
- Turbine cooling technology
- Bench scale development testing
- Fuels evaluation

Program Information Contact
Heat Engines
George Rudins (301) 353-5910

Magnetohydrodynamics

Program Objective

The objective of the Magnetohydrodynamics (MHD) program is to establish a suitable MHD technology base to allow industrial commercialization of MHD power plants in the future. MHD is a Carnot cycle system involving the direct conversion of thermal energy generated by the combustion of coal into electric power.

Areas Covered by Current Projects

- Technology Development
  - — Open-cycle MHD system components and subsystems testing.
- Research
  - — Basic and engineering studies on the subsystems of MHD close cycle processes.

Program Information Contact
Magnetohydrodynamics
George Rudins (301) 353-5910

Oil Shale

Program Objective

The primary objective of the Oil Shale program is to develop a sound base of technical information that will assist and support industry so that more of the Nation's oil shale resources can be utilized in an economical and environmentally acceptable manner. There are two interrelated objectives:

- The development of a sound engineering and scientific information base having broad application to the design of recovery processes that will be characterized by reduced cost and enhanced environmental acceptability; and the development, through proof-of-concept of novel ideas evolving from this work.
- The characterization of waste streams from oil shale conversion processes; and the design, test and evaluation of environmental control technologies applicable to oil shale processes.

Potential Areas for New Research Initiatives

- New approaches to control of emissions from oil shale retorting operations.
- New concepts to recover oil and energy values from oil shales.
- Develop new instrumentation techniques as applied to oil shale technology.
- Generic research to improve understanding of dynamic systems in shale processing.

Program Information Contact
Oil Shale
Jerry W. Ramsey (301) 353-3514

Surface Coal Gasification

Program Objective

The Surface Coal Gasification program has the mission of, and responsibility for, initiating and developing new technologies leading to commercially viable gasification process, components, and systems for converting coal to high, medium or low Btu gaseous and/or synthesis gas suitable for subsequent conversion into chemical feedstocks or liquid fuels. The program is responsible for the planning, coordination and effectiveness of process development programs as are performed in integrated benchscale systems, process development units (PDU) and, in some cases, pilot plants. Exploratory research and advanced development projects and/or studies are an important part of this activity. The program provides technical support and coordination with universities, industry, the Synthetic Fuels Corporation (SFC), the Tennessee Valley Authority (TVA), and other governmental agencies, as required, in order to accomplish the objectives of the Surface Coal Gasification program.

Areas Covered by Current Projects

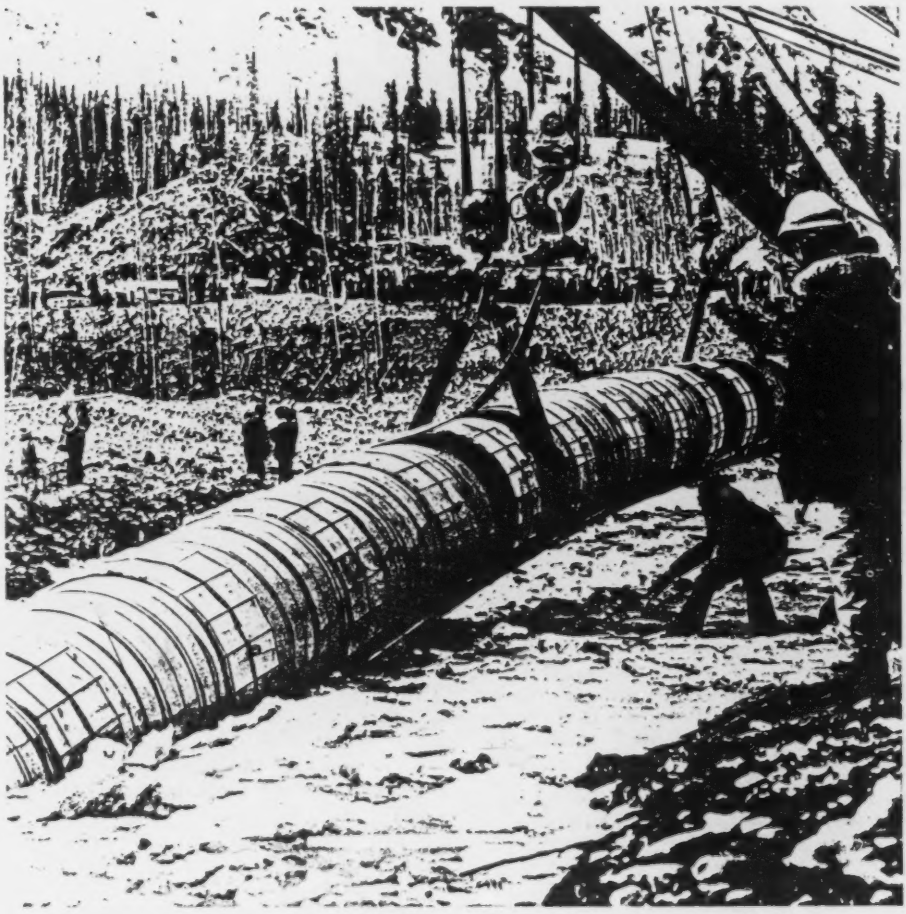
Technology Development

- Coal Gasification Processes—e.g., high, medium, low Btu gases, synthesis gas, hydrogasification, catalytic gasification.
- Gas Treatment/Cleanup Systems—e.g., acid gas removal, sulfur removal, tar/phenol decomposition and/or removal, etc.
- Waste Water/Effluent Treatment, and Control—e.g., impact of zero effluent discharge requirements, cooling tower studies, biologic treatment systems, process water reuse, etc.
- Operating Components, Materials Applications, Instruments, and Control Techniques—e.g., high performance valves, pumps, compressors, new alloys, coatings, claddings, new measurement techniques, instruments, etc.
- Modeling and systems analysis—e.g., process analysis, comparative economic systems, reactor modeling, data base management.

Research

- Fundamental Studies
  - — Modeling
  - — Kinetics
  - — Thermodynamics
  - — Catalysis & Reactions
  - — Mechanisms
  - — Hydrogasification
  - — Pyrolysis
  - — Fluidization
  - — Acid Gas Removal
  - — Hot Gas Removal
  - — Gas Separation
  - — Conversions
- Novel Gasification Concepts
  - — High Btu Processes
  - — Medium Btu Processes
  - — Low Btu Processes
- Environmental
  - — Waste Water Treatment
  - — Environmental Technology

Program Information Contact
Gasification
Lowell Miller (301) 353-3498



Unconventional Gas Recovery/ Underground Coal Gasification

Program Objective

The main objective of the Unconventional Gas program is to augment domestic gas supply through unconventional geologic sources. The current objectives of this program include: demonstration of field performance and acceptable predictive modeling capability for production of gas from unconventional gas sources; development of cost-effective diagnostic and extraction technologies required to produce gas efficiently and economically, and establishment of the necessary technology base in order to be able to identify production potentials from low permeability gas formations.

Areas Covered by Current Projects

Technology Development

- Gas recovery from Devonian shales;
- Gas recovery from western gas sands;
- Gas recovery from hydrates, deep sources, and coal seams.

Research

- Engineering and basic studies on gas recovery from Devonian shales, western gas sands, hydrates, deep gas sources, and coal seams.

Program Information Contact

Unconventional Gas Recovery/Underground Coal Gasification

Edward L. Burwell (301) 353-2724

Program Dedicated Facilities

Grand Forks Project Office (GFPO)
P.O. Box 7206, University Station
Grand Forks, North Dakota 58202

Harvey M. Ness
Director
Telephone Number: (701) 795-8170

The project office plans and manages the Department of Energy's contract research in low-rank coal and provides technical and financial oversight of this research and of the cooperative agreement with the University of North Dakota's Energy Research Center. In addition, the project office assists in the monitoring of the Great Plains Gasification Project at Beulah, North Dakota. The project office is under the direct management control of the Morgantown Energy Technology Center.

University of North Dakota Energy Research Center (UNDERC)
P.O. Box 8213, University Station
Grand Forks, North Dakota 58202

George A. Wiltsee
Director
Telephone Number: (701) 777-5134

Formerly known as the Grand Forks Energy Technology Center, the University of North Dakota Energy Research Center (UNDERC) is the center for research and applications of low-rank coals, which include lignite, subbituminous coal and peat. It conducts research for low-rank coals in environmental control technology, solvent liquefaction, atmospheric fluidized bed combustion, pulverized coal combustion, coal preparation, and slagging fixed-bed gasification to identify the technical, political, environmental, and economic restraints to expanded production of low-rank coals.

Laramie Project Office (LPO)
P.O. Box 1189
Laramie, Wyoming 82070

William E. Little
Director
Telephone Number: (307) 721-2247

The project office plans and manages the Department of Energy's contract research in oil shale, tar sands and underground coal conversion and provides technical and financial oversight of this research and of the cooperative agreement with the University of Wyoming's Western Research Institute. The project office is under the direct management control of the Morgantown Energy Technology Center.

Western Research Institute (WRI)
P.O. Box 3395, University Station
Laramie, Wyoming 82071

Wesley E. Barnes
Managing Director
Telephone Number: (307) 721-2212

Formerly known as the Laramie Energy Technology Center, the University of Wyoming's Western Research Institute is the center for research and applications related to oil shale, tar sands and underground coal gasification. Oil shale activities center around the development of processing technologies and environmental controls for the economical and safe production of shale oil. Tar sands research seeks to determine the recovery potential of domestic tar sands and the technology requirements for the recovery of oil. In underground coal gasification, the goal is to develop the technology to produce from coal deposits clean fuels suitable for commercial exploitation by conventional techniques.

Bartlesville Project Office (BPO)
U.S. Department of Energy
P.O. Box 1398
Bartlesville, Oklahoma 74005

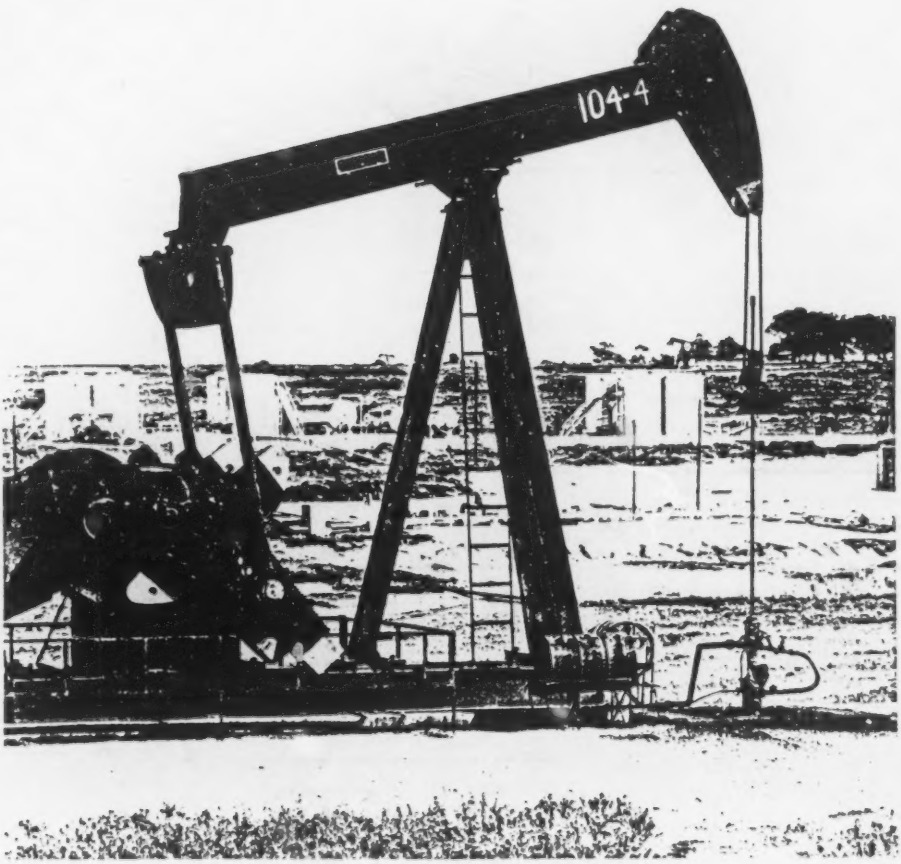
Robert L. Folstein
Director
Telephone Number: (918) 336-2400 x401

The project office plans and manages the Department of Energy's contract research in petroleum including enhanced oil recovery, fundamental hydrocarbon petroleum chemistry, thermodynamics, liquid hydrocarbon upgrading and processing, liquid fuels utilization and environmental and unconventional natural gas R&D. In addition, it provides technical and financial oversight of this research and the cooperative agreement with the National Institute for Petroleum and Energy Research, a government-owned laboratory run by IIT Research Institute. The project office is under the direct management control of the Assistant Secretary for Fossil Energy.

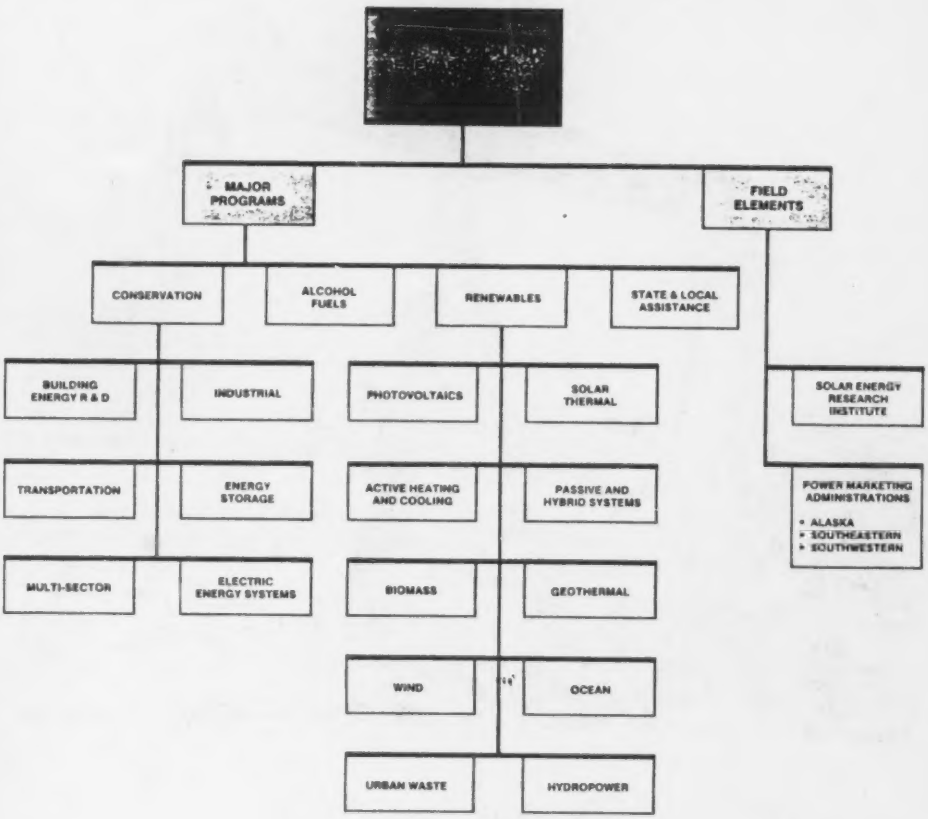
National Institute for Petroleum and Energy Research (NIPER)
P.O. Box 2128
Bartlesville, Oklahoma 74005

Richard Snow
Director
Telephone Number: (918) 336-2400 x200

Formerly known as the Bartlesville Energy Technology Center, the National Institute for Petroleum and Energy Research is a government owned facility that is operated by the Illinois Institute of Technology Research Institute (IIT) as a center for research on petroleum and other fossil fuel liquids. NIPER has active programs in enhanced oil recovery research including chemical flooding, carbon dioxide flooding and thermal treatments among others. Fuel utilization research encompasses the end-use requirements of the liquid fossil fuel cycle, including the characterization of new reference fuels, research on compatible end use systems to optimize energy usage and diesel engine research for stationary applications that is aimed toward operation with coal derived liquid fuels. Basic research on the physical, chemical and thermodynamic properties of fossil fuel liquids is also actively pursued.


104-4

Conservation and Renewable Energy



Assistant Secretary for Conservation and Renewable Energy

General Description

The Assistant Secretary for Conservation Renewable Energy is responsible both for programs which increase the efficiency of energy utilization and the amount of energy produced from renewable sources; and for the oversight and coordination of the Alaskan, Southeastern and Southwestern Power Marketing Administrations. The Conservation programs include: Building Energy R&D, Vehicle Energy R&D, Industrial, Energy Systems Research, Energy Storage, and Electric Energy Systems. Renewable Energy programs encompass: Photovoltaics, Solar Thermal, Geothermal, Biomass, Wind, Ocean, Active Solar, Passive Solar, Urban Waste, Hydropower and Alcohol Fuels. Power Marketing is comprised of five Administrations; i.e., Alaska, Bonneville, Southwestern, Southeastern and Western Area Power. Both Bonneville and Western Area Power Administrations report directly to the Secretary.

To achieve the energy conservation mission, selective problem-oriented basic research is conducted to develop a generic technology base that will support private sector initiatives to improve energy conversion and utilization. This enables the private sector to design and develop processes and equipment applicable to the transportation, buildings and industrial end-use sectors.

Renewables are inexhaustible or endlessly regenerative and can be grouped into two major categories: dispersed technologies applied directly by end-users and technologies for centralized utility applications. The objective of the renewable energy programs is achieved through research, development and proof-of-concept experiments to enable industry to bring efficient, economically competitive and environmentally acceptable renewable energy resources and technology options into the marketplace.

In this way, the Conservation and Renewable programs support research which attracts limited or no private venture capital because the risks are too high or the payoff is too long-range or unpredictable.

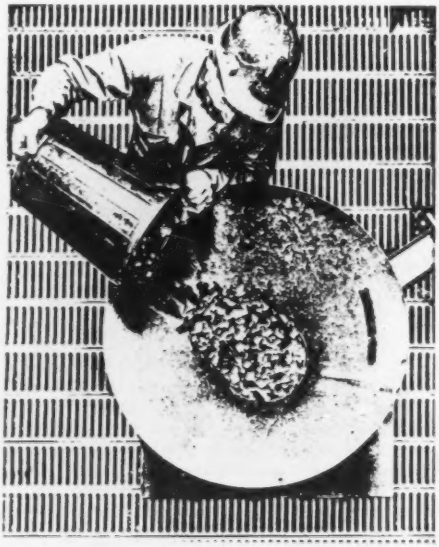
The third major area of responsibility for the Assistant Secretary is the oversight and coordination of policies and activities of three of the five Power Marketing Administrations to insure that Federal hydropower is marketed to promote widespread use at lowest cost and to promote energy conservation and the use of energy from renewable sources.

Field Elements

The Solar Energy Research Institute (SERI), Golden, Colorado, is the Nation's primary Federal laboratory for solar energy research and performs functions assigned by the Department of Energy in research, development and testing. SERI carries out its mission by conducting and coordinating long-term, high-risk research and development on renewable energy technologies which show promising evidence of ultimately competing in the marketplace, and which private industry cannot reasonably be expected to undertake. SERI's principal responsibilities are to carry out advanced scientific research in order to develop new technological options.

Proposal Review Procedures

Exceptions to the proposal review procedures discussed below may be found in the individual program summaries.



Unsolicited Proposals

Unsolicited proposals for submission to the Office of Conservation and Renewable Energy should be sent to:

Unsolicited Proposal Coordinator
Reports and Analysis Branch
Procurement and Assistance Management Directorate
U.S. Department of Energy
Washington, D.C. 20585

When an unsolicited proposal is received, it is first logged into the Procurement proposal tracking system and then referred to the appropriate program area for review. Program staff generally perform a preliminary review of the proposal to determine its relevance to program goals. If a proposal is deemed germane, a technical review will be performed either by program

staff, field personnel or peer groups. During the evaluation of the proposal, negotiations may take place to clarify the specific tasks of the proposed work. Based on the results of the technical review and the availability of funds, staff will then notify the proposer of acceptance or rejection of the proposal.

The Division of Technology Development and Analysis has decentralized project management for advanced heat engines, heavy duty transport and alternative fuels utilization to the National Aeronautics and Space Administration (NASA) Lewis Research Center in Cleveland, Ohio, and for advanced materials development to the Oak Ridge National Laboratory in Oak Ridge, Tennessee. Although DOE personnel may be contacted to discuss overall program research and development requirements, proposals will be directed to NASA and Oak Ridge National Laboratory for review.

Program Information Contacts
Conservation
Alan J. Streb (202) 252-9232
Renewable Energy
Robert San Martin (202) 252-9275

CONSERVATION

The goal of the Energy Conservation R&D Program is to conduct scientific and technical research in fields where new knowledge can expand the generic technology base underlying energy conservation. This will allow the private sector to develop ways to make more efficient use of available energy and to facilitate use of nonpetroleum energy sources. Programs in this research area include: Building Energy R&D, Energy Systems Research, Energy Storage, Electric Energy Systems, Industrial and Vehicle Energy R&D.

Building Energy Research and Development

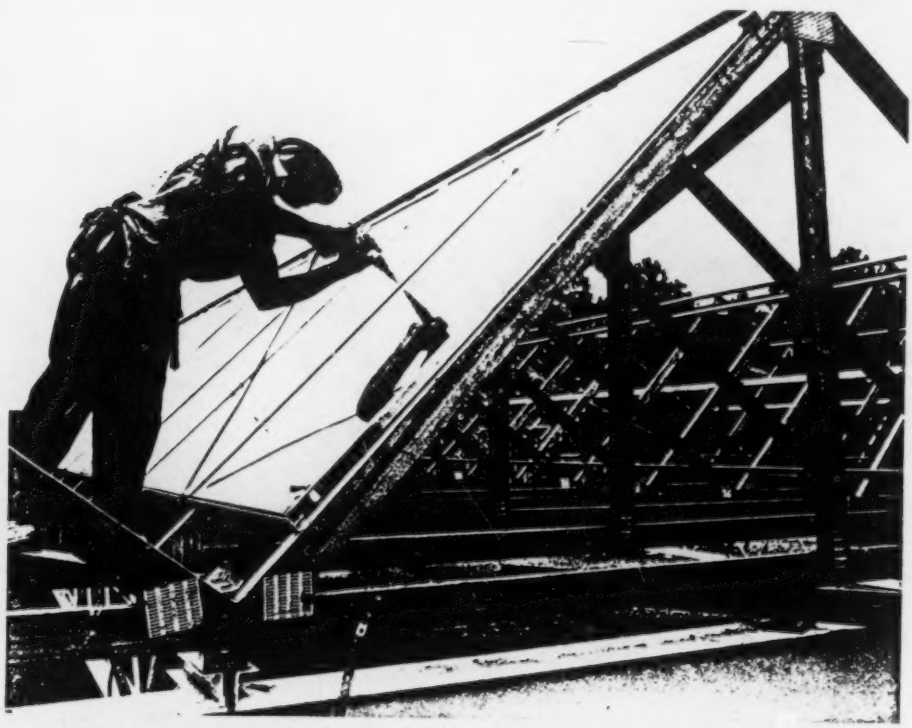
Program Objectives
The Office of Building Energy Research and Development (formerly Buildings and Community Systems) supports activities designed to increase energy utilization efficiency in commercial, residential and Federal buildings, and in entire communities through use of integrated community energy systems. Both research and development programs and regulatory approaches are used to encourage the adoption of energy conservation technologies. Efforts to increase the efficiency of consumer products and to transfer energy-efficient technologies to the private sector are vital aspects of the endeavor. (Although formerly a part of this office, programs to increase the use of urban waste as a source of energy are now administered by the Office of Renewable Technology.)

Potential Areas for New Research Initiatives
- Development of new concepts in building thermal envelope systems to provide better insulation, less infiltration, control of natural and artificial light, improved vapor barrier systems and better weathering.
- Development of test methods and procedures for determining static and dynamic thermal performance characteristics of materials, components and building systems.
- Determination of properties of insulating materials, including dependence of the properties on temperature, density and moisture.
- Increased research in indoor air quality, heat transfer, materials, structures and control technologies.
- Development of novel engine-drive/compressor systems for thermally activated heat pumps.
- Development of heat exchanger and combustion technologies employing new materials and processes to increase efficiency.
- Research on gas isotope enrichment, separation processes and lamp gas mixtures.
- Research on frosting/defrosting, cycling, fluid pairs and advanced insulation materials to improve refrigeration system efficiency.
- Systems analysis and research on thermodynamics, heat transfer, materials, structures, control technologies, combustion processes, and thermochemical/electrochemical processes as applied to community energy systems.

Program Information Contact
Building Energy Research and Development
Linda De La Croix (202) 252-9446

Energy Conversion and Utilization Technologies

Program Objectives
The Energy Conversion and Utilization Technologies (ECUT) program focuses on the development of advanced energy conversion and utilization technologies to improve energy efficiency, energy productivity, and fuel-switching capability for transportation, industry, residential/commercial and utility end-use sectors. Research is long-term, high risk applied and exploratory in nature, performed to establish the technical and economic feasibility of advanced energy conversion and utilization systems. Programs are developed and aimed at enhancing technology base and improving analytical capabilities in such research activities as engine combustion technology, tribology, and materials. To perform these tasks, ECUT maintains cooperative efforts with academia, national laboratories, and industry affording considerable opportunity for interdisciplinary review of technology needs, potential solutions to real problems, and effective technology transfer. ECUT programs are designed to provide developers of energy conversion and use technologies with comprehensive data bases and analytical and measurement techniques which will contribute to production of more efficient and reliable systems and components.



Problem Areas Requiring Additional Research

- Energy conversion technology—thermodynamics and fluid mechanics of closed system energy conversion, combustion processes of internal combustion engines, and physical and chemical aspects of alternative fuels for furnaces and boilers.
- Energy utilization technologies—study of heat transfer in harsh environments, physical and chemical separation techniques, and other energy intense processes, physical properties and structures of materials for using high temperature environments, and for reducing losses due to friction and wear.

Potential Areas for New Research

- Energy Conversion Technology
  - — Development of a complete understanding of velocities and turbulence levels at various points during engine operation, and how they can be controlled to appropriately tailor combustion processes of advanced engine concepts.
  - — Complete incorporation of technology base information and development of validated multi-dimensional large-scale computer models of complete engines for use in solving specific design problems.
  - — Assemblage of adequate data base of physical and chemical properties for select alternative fuels and experimentally evaluate several combustion parameters of interest to designers of furnaces and boilers.
  - — Experimental and analytical investigation of thermodynamics and fluid dynamics aspects of advanced closed cycle systems and components.
- Energy Utilization Technology
  - — Development of data bank for flow-induced vibration and two phase-flow studies in shell-and-tube heat exchangers, and investigation of coating techniques to enhance corrosion resistance of heat exchangers in moderate to high-temperature environments.
  - — Research on engineering of biocatalyzed processes for the production of bulk chemical commodities; definition of solvent/membrane characteristics to improve chemical separation techniques.
  - — Identificaion and testing of materials and lubricants with friction reducing characteristics.

Program Information Contacts

Energy Conversion Technology
Marvin Gunn (202) 252-1501

Energy Utilization Technologies
James Eberhardt (202) 252-1499

Electric Energy Systems

Program Objectives

The Division of Electric Energy Systems has as its primary concern those technologies relevant and applicable to U.S. electric energy systems. The overall objectives of the Electric Energy Systems program are to assist the private sector in the development of: (1) advanced technology options for the Nation's electric energy networks; (2) methodologies for integrating new technologies into electric utility systems; and (3) analytical procedures to assess and enhance the stability and efficiency of the country's increasingly complex interconnected electric energy system. Public concerns over health and safety, reliability, and costs have led to the initiation of innovative research in such areas as high-voltage systems, new materials, and sophisticated control methods.

The primary concerns of the program are:

- To accelerate the introduction of technology options that are critical for maintaining the country's electricity supply system (in both normal and emergency conditions) in a reliable, economic, and environmentally safe manner;
- To develop improved methodologies for planning and controlling complex, high-power electric systems;
- To support basic research on increasing the efficiency of electric energy supply and distribution, thus reducing primary energy use per unit of real GNP.

Potential Areas of New Research Initiatives

- Reliable Electric Power Delivery—Recent breakthroughs in new materials and control concepts show the potential for significantly improving our ability to maintain electric power continuity during periods of severe emergencies. New research is needed in such areas as: electromagnetic pulse protection, basic mechanisms of insulation failure, emergency detection and control, new systems analysis and equipment research, and system dynamic performance.
- Electric Field Effects—Public concern continues over the biological effects on humans, plants and animals from exposure to electric and magnetic fields arising from high voltage transmission of electric power. Research is needed in the low frequency range to clarify issues, to determine the threshold of effects and to assess the risk of undesirable effects from exposure to high voltage transmission lines.
- Systems Technologies—Increased system efficiency, greater fuel displacement (substitution of coal, nuclear and renewable resources for scarce, costly fuels), and enhanced resource management are attainable through research in advanced optimization concepts, and materials and systems technologies. Opportunities for new research exist in such areas as: superconducting power generation and transmission technologies; underground and submarine cables; advanced electrical insulation technology; high efficiency materials; advanced batteries for utility storage; communication and control concepts; multiterminal, high-voltage, direct current transmission systems; and advanced systems simulation analytical methods.

Program Information Contact
Electric Energy Systems
Raymond Dunlop (202) 252-4564

Energy from Municipal Waste

Program Objective

The DOE Energy from Municipal Waste program seeks to provide the generic technology and data base with which local government and private industry can bring Energy from Municipal Waste technologies into the marketplace and increase the efficiency of energy production and utilization. Research is conducted to provide a data base on liquids and gas production and to provide a basis for environmental and feedstocks preparation.

Potential Areas for New Research Initiatives

- Thermochemical studies to provide a generic technology base for systems producing liquid and gaseous fuels.
  - — Combustion tasks concerned with kinetics, efficiency, and products formation for corrosion and pollution control.
  - — Pyrolysis tasks concerned with base data development on effects of various feedstock components and of time, temperature, pressure, etc.
- Biochemical studies to provide data on biochemistry and life support systems of anaerobes. Water and wastewater studies to provide information to improve energy efficiency in treatment systems.
- Mechanical studies to provide generic data on processing generic data on systems design will be developed for use by design engineers. Improved densification techniques and binders.

Program Information Contact
Energy from Municipal Waste
Donald K. Walter (202) 252-6104

Energy Storage Systems

Program Objectives

Energy Storage supports end-use programs in their critical energy-saving and fuel substitution missions. When used in the link between energy source and end-use, storage can correct the timing mismatch between energy supply and energy demand found in most energy delivery systems. This is particularly important in the case of intermittent energy sources such as solar, or in production and delivery systems where demand fluctuates greatly, as with electricity.

The Energy Storage Program goals are to increase the substitution of coal, nuclear and solar energy for petroleum and natural gas; to enable solar and other intermittent

energy systems to provide continuous service; and to conserve energy by storing industrial and utility reject heat for later use and by improving the efficiency of electrochemical processes.

DOE is developing four major energy storage technologies: (1) battery; (2) mechanical; (3) thermal; and (4) chemical energy storage. These technologies will be used throughout the U.S. economy in solar systems, transportation, building heating and cooling, industry, and the utilities.

Problem Areas Requiring Additional Research

- Development of cost-effective batteries with high energy density and peak power capacity, as well as long cycle life for transportation, solar, and utility applications;
- Electrochemical energy conversion, including regenerative EMF systems, fuel cells, etc;
- Development of new methods of hydrogen production from water, using heat or sunlight;
- Development of higher-temperature superconductors;
- Development of more efficient heat transport process investigation into reversible thermochemical reactions;
- Development of a data base containing the thermophysical properties of materials used in energy storage systems.

Potential Areas for New Research Initiatives

- Theory and properties of aqueous, nonaqueous, and solid electrolytes;
- Membrane properties and characteristics of ion exchange materials;
- Structural aspects of electrolytic interfaces, particularly solid-liquid;
- Electric double-layer phenomena at solid-liquid interfaces;
- Characteristics of mechanisms and rates of electrochemical reactions in electrolytic solutions;
- Electrocatalytic theory and material properties for increasing and controlling electrochemical reaction rates;
- Experimental methods and instrumentation in electrochemical kinetic theory research and development;
- Theory and characteristics of electrocrystallization and material dissolution;
- Electrolytic corrosion and passivation theory and technique for electrolytic materials treatment and stabilization;
- Mechanisms of electrophoretic deposition and materials characteristics;
- Electrochemical ion transport phenomena mechanisms and characteristics;
- Materials research relative to electrochemical systems;
- Thermochemical reactions and reactant properties for heat transport;
- Solid-solid phase change materials for thermal storage.

Program Information Contact
Energy Storage Systems
John J. Brogan (202) 252-1477

Industrial Programs

Program Objectives

The Industrial Programs identify energy conserving industrial techniques and sponsor cost-shared research and development to develop and transfer technology to the private sector. Program efforts are aimed at increasing energy utilization efficiency, substituting more abundant fuels for scarce oil and natural gas in the industrial and agricultural sectors, and minimizing energy loss in waste streams of all types. To complement these efforts, programs are maintained to monitor industry's progress toward improved energy efficiency and to transfer existing and new technology to the private sector. The overall emphasis of these efforts is to encourage an increase in the rate of adoption of energy conservation measures and investments by the industrial sector and to accelerate the introduction of higher-risk technologies which offer significant energy conservation potential.

Problem Areas Requiring Research

- Waste energy utilization and cogeneration—basic work in thermodynamics, heat transfer, materials, combustion processes, and thermochemical/electrochemical processes;
- Alternative materials utilization—basic research on physical properties and structures of proposed alternative materials, and materials recovery techniques;
- High and low temperature processes—basic work in phase equilibria, metallurgy, solids flow, process control technology, and improved materials; and
- Agriculture and food processes—basic research in nitrogen fixation, food preservation, and advanced food processing.

Potential Areas for New Research Initiatives

- Improvement of combustion efficiency through better control of turbulence and reaction rates;
- Research on the chemical kinetics of important processes, especially heterogeneous gas solid and gas liquid kinetics;
- Development of ceramics, metal alloys, and coatings for high-temperature applications;
- Development of research techniques that explore the chemistry and physics of membrane separation of air into nitrogen-rich and oxygen-rich streams, and for separation of mixed liquid streams;
- Development of models of the thermodynamic properties of important materials;
- Basic research in metal solidification processes, nature of coking phenomenon, basic mechanisms of ore grinding, and iron oxide reduction;

- Development of artificial photosynthesis techniques;
- Development of advanced separation techniques for more efficient water removal from solids and liquids; and
- Research on catalysts and catalytic reactions for low temperature chemical processing.

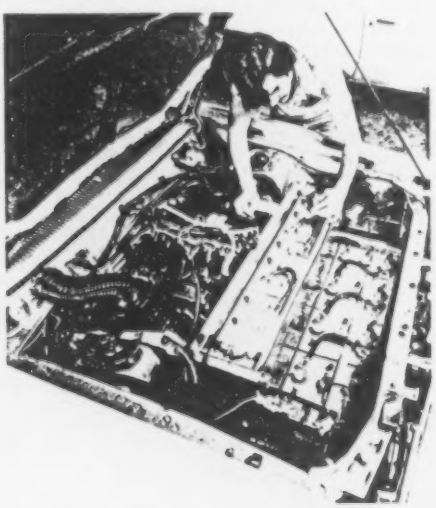
Program Information Contacts

Waste Energy Recovery	
Albert Hayes	(202) 252-2378
Waste Products Utilization	
Jerome Collins	(202) 252-2369
Advanced Extraction, Reduction and Melting Processes	
Ralph Sheneman	(202) 252-2080
Advanced Concentration and Evaporation	
Ernest Loeb	(202) 252-2075
Integrated Energy Systems	
Tyler Williams	(202) 252-2371

Vehicle and Engine R&D

Program Objectives

The Vehicle and Engine R&D programs are aimed at reducing the transportation sector's vulnerability to petroleum shortages by developing more energy efficient vehicle propulsion system options and by developing the ability to switch from petroleum to electricity and alternative fuels. Emphasis is placed on advancing heat engine technology through the development of component and materials technologies; supporting long-term, high-risk technology research and development for petroleum savings in the heavy duty transport sector; advancing electric and hybrid vehicle technology; and developing means of using alternative fuels in vehicles.



Potential Areas for New Research Initiatives

- Develoment of new concepts and techniques for assessing and utilizing fuels from synthetic crude oil;
- Lightweight hydrogen storage materials or techniques for hydrogen-fueled vehicles;
- Data on composition of exhaust from combustion and synthetic fuels;
- High-strength, high-temperature ceramics; and
- High-temperature waste heat utilization concepts.

In addition, goal-oriented research related to battery development is needed in the following areas:

- Corrosion in battery and fuel cell environments;
- Ionic conductivity of solid electrolytes;
- Catalysts associated with air electrodes and hydrocarbon reformers;
- Material migration;
- Electronic conductivity of sulfur compound electrodes;
- Low-cost electronic insulators;
- Surface phenomena of porous electrodes; and
- Organic electrolytes for secondary batteries.

Program Information Contacts

Advanced Heat Engines	
Richard Alpaugh	(202) 252-8012
Heavy Duty Transport	
Edgar Gregory	(202) 252-8055
Alternative Fuels	
Ralph Fleming	(202) 252-8055
Electric and Hybrid Vehicles	
Diane Pero	(202) 252-8044

RENEWABLE ENERGY

Renewable energy resources offer the potential for significant contributions toward achieving energy self-sufficiency over the long-term. In addition to the direct solar energy technologies, such as photovoltaics, active/passive solar and thermal, this category also includes R&D in biomass, ocean, wind and geothermal energy technology.

Active Heating and Cooling

Program Objective

The DOE Active Heating and Cooling program seeks to improve the performance/cost ratio of active solar space conditioning systems by a factor of two-to-four. Research and development are performed on materials, components and prototype systems.

Potential Areas for New Research Initiatives

- Develop and test polymeric collectors to reduce cost and improve performance;
- Test and evaluate performance of evacuated tube collectors and compound parabolic concentrators;
- Research to obtain information on solid desiccant cooling systems.

Program Information Contact

Active Heating and Cooling	
John Schuler	(202) 252-8150

Biomass Energy Technology

Program Objective
The DOE Biomass Energy Technology program seeks to provide the generic technology base for biomass energy production and conversion which reduces uncertainty to the point at which industry will invest in biomass technology development.

Potential Areas for New Research Initiatives
- Attain understanding of fundamental processes for thermochemical conversion of biomass into gaseous and liquid fuels.
- Establish the technology data base for photobiological production of hydrogen.
- Establish a suitable technology base and basic understanding of the biological conversion of cellulosic material.
- Examine aquatic species production through species screening and improved cultural practices.

Program Information Contact
Biomass Energy Technology
Beverly Berger (202) 252-6750

Geothermal and Hydroelectric Energy Technologies

Program Objectives
The objective of the Geothermal and Hydropower programs is to build a broad technology base that will be used by the private sector to exploit the Nation's extensive geothermal resources (hydrothermal, geopressured, and hot dry rock) and small-scale hydropower resources. Research efforts related to hydrothermal resources address risks perceived by the private sector in the area of reservoir capacity and longevity, the high cost of exploration and reservoir development, commercial scale plant economics, environmental effects of production, and unproven energy extraction and conversion technologies. Geopressured wells are being tested to determine magnitude, availability and producibility of geopressured resources for recovery of methane, and hydraulic and thermal energy. The technical feasibility of extracting thermal energy from hot dry rock resources is being determined by creating and operating a large scale multifracture thermal loop in deep rock formations. R&D efforts related to small-scale hydropower resources have involved field tests of minimum stream flow requirements and Schneider engine and marine thruster engineering development.

Potential Areas for New Research Initiatives
- Development of drilling equipment and techniques that will lead to higher penetration rates, longer bit lives, and improved directional drilling.
- Development of electronics and instrumentation for mapping wellbore fractures, assessing the integrity of the cement bond, and determining the trajectory of the wellbore.
- Evaluation of precipitation and scale control techniques, brine treatment/disposal, and cooling water systems.
- Development of non-destructive evaluation techniques for drilling components, well completion materials, and energy conversion component materials in order to predict and prevent failure.
- Development of more accurate and cost-efficient tools, techniques and models for geothermal exploration leading to the improvement of geochemical and high-resolution geophysical techniques for all types of hydrothermal reservoirs.
- Development of improved reservoir engineering techniques for determination of the extent of a reservoir and its porosity, permeability, and recharge mechanism through improved well testing, log interpretation and reservoir modeling techniques.
- Injection of spent geothermal brines into deep reservoir formations, including study of the need for and techniques for chemical pre-treatment and solids removal.

Program Information Contact
Geothermal and Hydroelectric Energy Technologies
John Mock (202) 252-5340

Ocean Energy Technology

Program Objective
The DOE Ocean Energy Technology program seeks to provide a technology base that will enable private industry to develop and commercialize ocean energy technology.

Potential Areas for New Research Initiatives
- Development of materials and manufacturing processes for higher efficiency that can be obtained with current state-of-the-art heat exchangers operating at temperature differences of approximately 20°C.

Proposal Review Procedure
After a proposal has been logged into the DOE proposal tracking system, it is either evaluated by the Headquarters program staff or forwarded to the proper DOE laboratory for review and action. The forwarding of the proposal to the DOE laboratory is the normal course of action. Based on the results of the technical review and the availability of funds, staff will then notify the proposer of acceptance or rejection of the proposal.

Program Information Contact
Ocean Energy Technology
William E. Richards (202) 252-5517

Passive and Hybrid Solar Program

Program Objectives

The DOE Passive and Hybrid Solar Program seeks to improve performance of passive and hybrid (mixed active and passive) solar buildings through research and development on systems, components, and materials.

Potential Areas for New Research Initiatives

- Basic physical studies in aperture materials, storage materials and heat transfer.
- Performance analysis which includes:
  - — Strategies for integrating passive heating, cooling, and daylighting designs with conventional non-residential building energy systems;
  - — Strategies for reducing or avoiding cooling loads in residential buildings;
  - — Performance characterization of daylighting systems in non-residential buildings;
  - — Analysis of passive cooling technologies; and
  - — Building energy analysis simulations and computer code validations.

Program Information Contact
Passive and Hybrid Solar Program
Lawnie H. Taylor (202) 252-8103

Photovoltaic Energy Technology

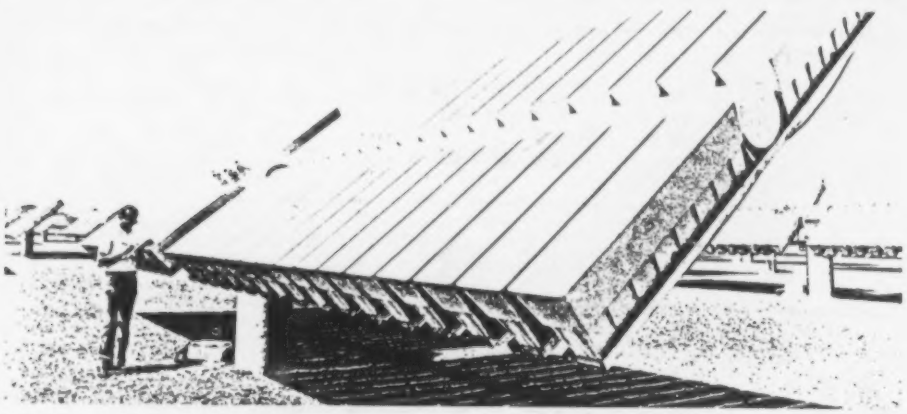
Program Objectives

The DOE Photovoltaic Energy Technology program seeks to advance scientific understanding and to enlarge the technology base needed for the private sector to develop and utilize advanced photovoltaic energy systems. Efforts of this program are focused on increasing the understanding of physical phenomena and defining, analyzing and testing materials, conversion devices and system concepts as well as establishing a technical feasibility of advanced cells and systems. Other primary concerns of this program are to improve sunlight-to-electricity conversion efficiencies, to increase the stability of the semi-conductor materials and conversion devices, to enhance the reliability of components and systems, to seek low-cost materials and processes, and to obtain experimental data on the performance of devices and systems.

Potential Areas for New Research Initiatives

Research on the conversion of sunlight directly into electricity (which involves the motion of free electrons within semi-conductor materials under the stimulation of electromagnetic radiation in the visible and near-visible spectrum) includes theoretical and applied physics, inorganic and organic chemistry, and electronic/electrical and materials engineering. Opportunities include:

- Materials Research (supports research on properties of photovoltaic materials, screening of new materials, material interfaces, reaction kinetics and thermodynamics, defect chemistry, materials stability, etc.).
  - — Research on reaction kinetics and thermodynamics of silane pyrolysis in a particulate silicon media (to determine, for example, if the pyrolysis is a homogeneous, heterogeneous or autocatalytic reaction); chlorosilane formation, disproportionation and pyrolysis reactions.
  - — Basic research and testing of amorphous materials.
    - – Fundamental understanding of glow discharge amorphous silicon-hydrogen.
    - – Deposition techniques such as sputtering and chemical vapor disposition that show promise for improved film properties and capability for large area, uniform deposition with high deposition rates.
    - – Plasmadynamics of large area glow discharges for fabricating thin films of amorphous silicon-hydrogen.
    - – Fundamental properties of other amorphous materials such as amorphous silicon-carbide.
    - – Interfaces between dissimilar amorphous materials such as amorphous silicon-hydrogen with indium tin oxide.
  - — Basic and applied research on crystal silicon.
    - – Basic mechanisms of point, line and area defects in silicon crystals and their effect on semi-conductor characteristics.
    - – Growth mechanisms in silicon sheets that control the presence of dislocations and other structural defects and of chemical impurity clusters.
  - — Research on materials for thin-film polycrystalline cells.
    - – Interface between cadmium-zinc-sulfide and copper-indium-diselenide to reduce interface states and decrease recombination losses.
    - – Improved stoichiometry and crystal perfection by the use of electrochemical deposition techniques, particularly for cadmium telluride.
  - — Research on growth theory for multibandgap materials, new materials for very high efficiency cells and fluorescing materials for luminescent concentrator devices.
    - – Thin film arsenide materials growth for single crystal cells using thin film separation techniques, silicon substrates, etc.
    - – Cascade cell materials growth studies.
    - – Multilayer optical coatings for maximum spectral utilization and research on new contact metallurgy which allows for high current densities at solar radiation concentration ratios up to 1000 suns.
    - – Organic and inorganic luminescent concentrator materials; continuing photochemical research for enhanced energy transfer between luminescent centers; and studying triplet state quenching to inhibit long-term photon damage to organic dye molecules.
  - — Photovoltaic electrochemical mechanisms research.
    - – Semi-conductor materials, electrolyte and redox-couple chemistry and multivalent storage chemistry for photovoltaic electrochemical solar cells with storage capability.
- *Advanced Concepts Research* (understanding the fundamental physical phenomena associated with advanced concepts such as thin films cells, multibandgap cells, luminescent concentrators, etc.).
  - — Advanced cells concepts including analysis of layer thickness, concentration gradients and contact



metallurgy, for improved open circuit voltage, short circuit current and fill factor.
  - — Novel concepts for cascade cell interconnections, such as superlattice, and for diffused connection, laser recrystallization and interface modification.
- *Supporting Research and Measurements* (provides improved techniques for measuring material and device properties, including methodology and interpretation for accelerated lifetime testing, and program management studies.)
  - — Measurement techniques for understanding the stability of thin-film compounds and amorphous cells with emphasis on identification of degradation mechanisms.
  - — Validation of accelerated life test models and techniques for extrapolating silicon photovoltaic module performance to a 20-year service life.
  - — Theoretical models for predicting output characteristics of concentrator array subsystems with feedback to device/module intergration.
  - — Improved methods of examining semi-conductor, metal and insulator interfaces. The rapidly expanding private sector offers increasing opportunities for research and development activity, especially investigations offering near-term applications.

Program Information Contact
Photovoltaic Energy Technology
Robert Annan (202) 252-1720

Solar Thermal Energy Technology

Program Objectives
The DOE Solar Thermal Energy Technology program seeks basic research and development of materials, processes, components and systems for the generation of thermal, mechanical and electrical power, and for thermochemical or photochemical production of petrochemical substitutes using concentrated solar energy. Efforts of this program are focused on cost and performance improvements and acceptable reliability, durability and safety characteristics.

Potential Areas for New Research Initiatives
- Development of high temperature, high flux concentrating collectors and receivers for the efficient production of process heat and electric power.
- Development of low-cost concentrators utilizing metalized polymeric reflecting surfaces and innovative geometric configurations.
- Identification and engineering of solar-enhanced processes for the production of fuels and chemicals.

Program Information Contact
Solar Thermal Energy Technology
Frank (Tex) Wilkins (202) 252-1684

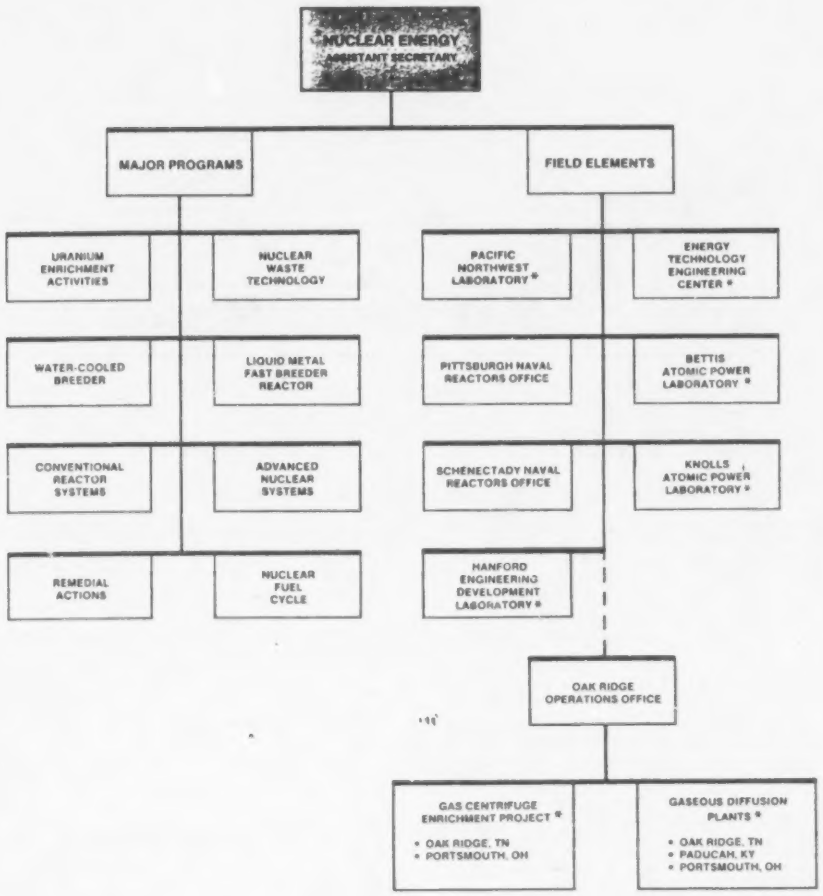
Wind Energy Technology

Program Objectives
The Wind Energy Technology program seeks to provide a technology base that will enable the private sector to develop and utilize wind energy systems.

Potential Areas for New Research Initiatives
- Advanced concepts and research for improving aerodynamic performance and design analysis methods for wind turbines;
- Theory and models for predicting aeroelastic and structural dynamics characteristics;
- High strength, low-cost motor blade materials;
- Ultra-high cycle blade fatigue life prediction methods.

Program Information Contact
Wind Energy Technology
Louis Divone (202) 252-5540

Nuclear Energy

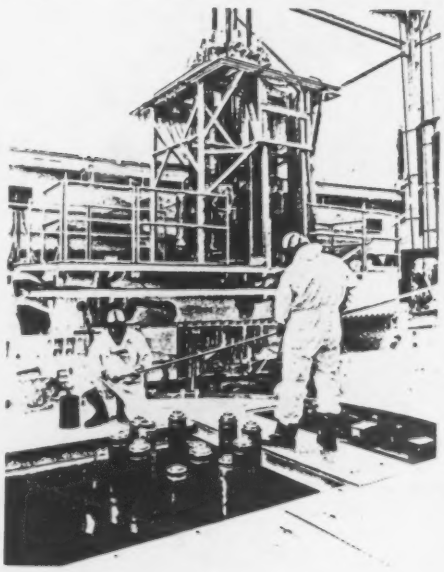


* CONTRACTOR OPERATED FACILITIES

Assistant Secretary for Nuclear Energy

General Description

The Assistant Secretary for Nuclear Energy (NE) is responsible for the administration of nuclear fission power generation and fuel technology, including breeder reactor technology; the evaluation of alternative reactor fuel cycle concepts; development of space nuclear generator systems; uranium enrichment activities, including development of advanced enrichment technology; development of naval nuclear propulsion plants and reactor cores; nuclear waste technology; remedial action program; and nuclear fuel cycle research and development. Much of the Nuclear Energy effort is directed toward technology and engineering development programs which is performed by DOE laboratories and other major industrial contractors. Several programs of potential interest to researchers are discussed on the following pages.



Field Elements

The major test facilities for the Office of Nuclear Energy are located at the Argonne National Laboratory (ANL), and the following program dedicated sites: the Bettis Atomic Power Laboratory, the Energy Technology Engineering Center (ETEC), the Hanford Engineering Development Laboratory (HEDL) and the Knolls Atomic Power Laboratory (KAPL). Existing test facilities are operated and maintained, in support of the plant projects and breeder technology elements of the Liquid Metal Fast Breeder Reactor (LMFBR) program in accordance with technical requirements, priorities, and scheduled needs identified under those elements, consistent with safe, efficient operation and acquisition practices. For further information on these program dedicated facilities, please refer to the summaries at the end of this section.

The field elements of the Breeder Reactor Technology base program are composed of test facilities and contractors which include national laboratories, universities and industry. Test facilities are an essential part of the LMFBR program in that they provide the capability to test systems and components developed under the breeder technology program, as well as prototypes and models of components to be incorporated into plant projects. Through operation of irradiation facilities such as the Fast Flux Test Facility (FFTF) and Experimental Breeder Reactor (EBR II), and operation of large nonnuclear sodium facilities, plant performance information on operation and maintenance is also generated to support plant projects. The Clinch River Breeder Reactor Plant (CRBRP) project office, located at Oak Ridge, Tennessee, is the primary field element for the closeout activities of the CRBRP project.

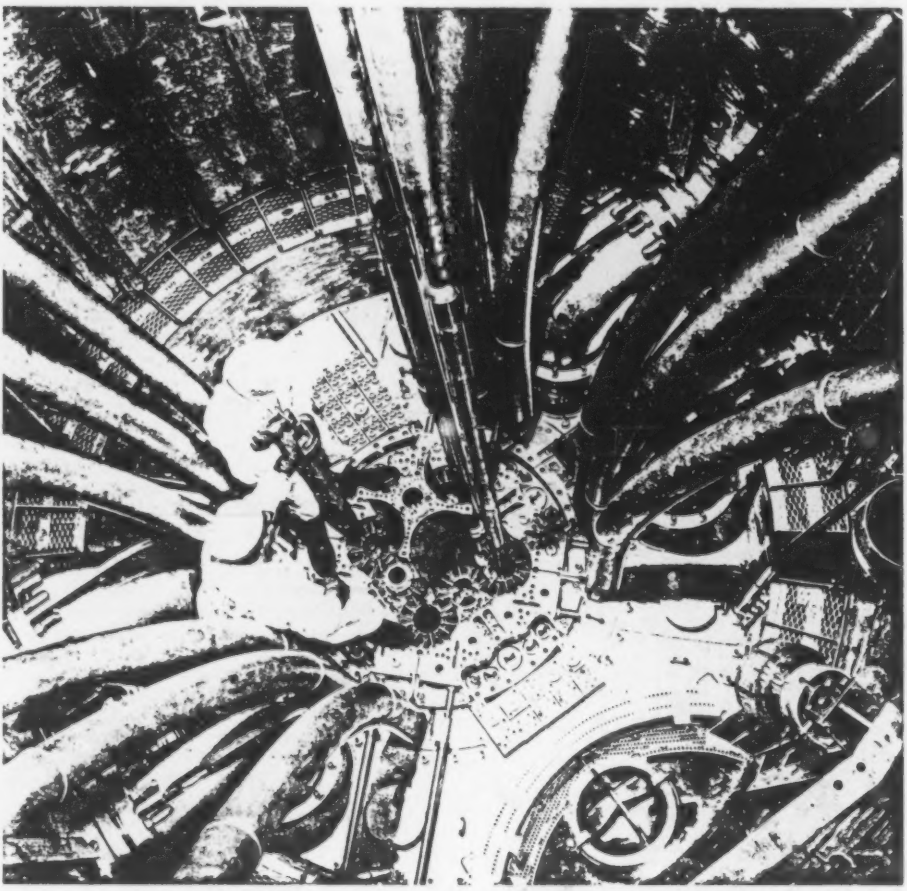
Mission system development work is usually performed by the industrial contractors. Fuel and safety research and development, special metals technology research and development, capsule hardware fabrication, and heat source assembly are done in Government-owned contractor-operated laboratories and plants because these operations depend on the nuclear facilities, equipment, and expertise maintained for nuclear fuel and weapons programs.

Qualification and flight acceptance tests of the isotope space power converter subsystems are supported by the Mound Plant, Miamisburg, Ohio. Iridium blanks fabricated at the Oak Ridge National Laboratory, will be provided to the Mound Plant where the iridium is formed into fuel capsule containers. The Savannah River Plant will manufacture 63-watt thermal pellets of plutonium-238 and encapsulate them into the thermoelectric converter hardware by Mound Plant staff. Safety analyses and safety testing by the Los Alamos National Laboratory will be conducted on representative flight isotope hardware components to assess the safety margin of the system.

Proposal Review Procedures

All unsolicited proposals for submission to the Office of Nuclear Energy should be sent to:

Unsolicited Proposal Coordinator
Reports and Analysis Branch
Procurement and Assistance Management Directorate
U.S. Department of Energy
Washington, D.C. 20585



The proposals will be logged into the DOE proposal system and will be sent to the responsible program official for evaluation. The proposals are generally reviewed by in-house program staff but, in some instances, the program official may have the proposal reviewed by scientists/engineers in the field laboratory facilities. In such cases, the prior written permission of the proposer is obtained. A technical evaluation is prepared by the cognizant program office representative and, based on the evaluation, funding recommendations are made.

The Office of Converter Reactor Systems generally uses a Notice of Program Interest (NPI), to encourage proposal submission for its programs. This notice describes an interest by DOE in innovative approaches to specific problem areas. NPI's are not formal solicitations, but are used instead as a communications device to aid potential proposers in focusing on areas where proposals may be mutually beneficial to DOE programs and the proposer. NPI's are generally published in the *Commerce Business Daily* or the *Federal Register* and are widely distributed.

Program Information Contact
General Information
Alexander S. Lyman (301) 353-4380

Advanced Nuclear Systems Programs

Program Objectives
The role of the Advanced Nuclear Systems Program is to respond to Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) requirements for the design, development, and delivery of space nuclear power systems. The program at present

consists of three projects: Static Outer-Planetary Radioisotope Thermoelectric Generator (RTG) project—developing RTG's for NASA Galileo mission to be launched in 1986 and the Space Reactor Development Program—an advanced technology readiness program for both civilian and military missions in the more distant future; and a terrestrial RTG project that is classified.

Program Structure

The Advanced Nuclear Systems program is responsible for the development and delivery of nuclear power sources for U.S. military and civilian space and terrestrial missions and for the assessment/maintenance of these nuclear energy sources consistent with the agency's health and safety requirements. The program consists of three broad elements: Flight Systems Development, Flight Systems Support, and Special Applications.

Flight Systems Development includes the design, development, fabrication, assembly, and test of isotopic space power systems on a revised schedule for the NASA Galileo and International Solar Polar Spacecraft. Also included is the development of a space nuclear reactor power source capable of producing electricity in the 100 Kw(e) power range or above. Another major activity is a technology program aimed at demonstrating a new, light weight, radioisotope thermoelectric generator (RTG) design that takes advantage of improved thermoelectric materials, new fabrication techniques, and new design concepts (MITG).

Flight Systems Support covers fabrication of plutonium fuel necessary for flight spacecraft missions as well as for the safety and environmental efforts. It also includes basic space nuclear power system technology development and support of the flight system program.

Special Applications includes design and integration studies. Activities such as development tests on advanced RTG components aimed at extending power system lifetimes, minimizing personnel exposure operations, and analyses of compact nuclear related studies, assessments and nuclear training programs are also supported.

Program Information Contact
Advanced Nuclear Systems
Earl Wahlquist (301) 353-3795

Converter Reactor Systems

Program Objectives

The Light Water Reactor (LWR) Program, the High Temperature Reactor (HTR) Program, the Advanced Reactor Systems Program, and the Three Mile Island Activities Program make up the elements of Converter Reactor Systems. Programs supported by the Department in the LWR area seek to improve plant safety, reduce occupational exposure to radiation, reduce plant lead times, improve the efficiency of uranium fuel, and enhance converter reactor deployment through institutional, regulatory reform measures. For the HTR Program, the Department will be pursuing design and development activities to support the process steam/cogeneration concept which has been decided upon as the lead plant project. The Advanced Reactor Systems Program has the objective of developing and demonstrating proliferation-resistant reduced enrichment fuels for research and test reactors. Finally, the Department maintains a research program to determine the causes for and safety implications of the accident in 1979 at the Three Mile Island nuclear electric plant in Pennsylvania and to develop recommendations for improving the safety and reliability of all nuclear plants. In 1981, the Department started a program to remove and stabilize, and dispose of all the abnormal waste generated during the accident.

Potential Areas for New Research Initiatives

- Fuel safety technology development;
- LWR water chemistry;
- Education and training of plant operations personnel;
- Advanced instrumentation for powerplants;
- Waste immobilization; and
- Licensing and regulatory reform.

Program Information Contact
Converter Reactor Systems
Jerry D. Griffith (301) 353-3773

Liquid Metal Fast Breeder Reactor Program

Program Objectives

The Liquid Metal Fast Breeder Reactor Program (LMFBR) is a research, design, and development program to confirm the economics, safety, and reliability of breeder reactor systems in support of the timely and effective integration of these reactors with the current nuclear industry and fuel cycle technology. LMFBR technology is being developed by the base program to solve the long-lead time technical problems before reactor demonstration takes place. At the same time, the Department is pursuing the main-line reactor project developmental efforts, which include the operation of the 400 megawatt (thermal) Fast Flux Test Facility and construction of the Fuels and Materials Examination Facility at Richland, Washington and the advanced Conceptual Design Study of the 1000 megawatt (electrical) Large Scale Prototype Breeder.

Program Structure

The thrust of the Breeder Reactor Systems program is to complete the research and development of breeder reactor technology to the level that is appropriate for transfer to industry. The private sector has the ultimate responsibility for plant investment and commercialization of the technology. The program includes a supporting technology base program, which covers test facility construction and operation technology research and development efforts in reactor fuels, components, physics, and safety. These elements are closely integrated and are directed at breeder powerplant development, focusing on the development of an economically competitive breeder that is inherently safe.

Potential Areas for New Research Initiatives
Methodology, systems, and hardware to:

- Improve plant reliability;
- Reduce plant capital costs;
- Improve fuel performance and breeding; and
- Ensure plant safety.

Program Information Contact
Liquid Metal Fast Breeder Reactor
Earl Wahlquist (301) 353-3795

Nuclear Fuel Cycle

Program Objectives
The Nuclear Fuel Cycle program provides for development and demonstration of advanced technology for reprocessing of irradiated fuels from nuclear power reactors. Primary emphasis of the development and demonstration effort is on the more stringent requirements associated with reprocessing of Fast Breeder Reactor (FBR) fuels, including the higher thermal and radiation burdens, higher fissile content, sodium contamination, and heavier fuel assembly structures. Advanced developments for FBR fuel reprocessing will be available for use by future light water reactor fuel reprocessors. The technical program focuses on development and demonstration of reprocessing technology that will provide for reduced radiation exposure to workers, increased environmental protection, increased reliability, enhanced safeguards, and reduced costs.

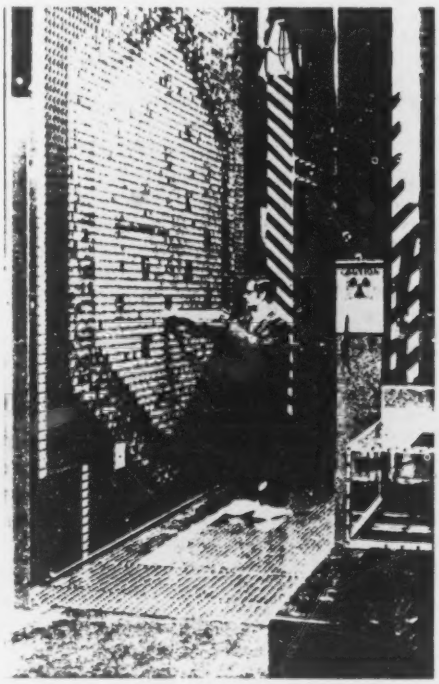
Potential Areas for New Research Initiatives

- Radiation hardening of instrumentation, TV cameras, other electronic equipment.
- Man-machine interface in a nuclear environment, i.e., performance of humans under more complex and sophisticated operating conditions.
- Advanced manipulator development for remote maintenance, i.e., more rugged components, improved instrumentation and controls, force reflection.

Program Information Contact
Nuclear Fuel Cycle
Vicki Barden (301) 353-5019

Nuclear Waste Technology

Program Objectives
The objective of the Nuclear Waste Technology program is to support technology related to the long-term management and disposal of commercial radioactive waste. Included are only those activities under the responsibility of the Assistant Secretary for Nuclear Energy which were previously part of the Commercial Waste Management decision unit and are not covered by the Office of Civilian Radioactive Waste Management under the Nuclear Waste Policy Act of 1982. Specific activities include:(1) assistance to the states to develop regional compacts for the disposal of low-level waste; and (2) development, selection, and demonstration of



waste treatment and solidification processes suitable for disposal in a repository.

Potential Areas for New Research

- Development of improved techniques for low-level waste disposal.
- Development of waste technology to support handling, immobilization and disposal of transuranic and high-level wastes.

Program Information Contact
Nuclear Waste Technology
Joseph A. Coleman (301) 353-4728
(excludes activities under the Nuclear Waste Policy Act of 1982)

Remedial Actions

Program Objectives
The objective of the Remedial Actions program is to treat or stabilize radioactive wastes and perform required decontamination and decommissioning at contaminated DOE and legislatively dictated non-government facilities and sites. The general approach applied to fulfilling this objective is (1) to verify the need for remedial action by conducting radiological surveys of suspected contaminated properties; (2) to define the method of accomplishing required remedial action, based on existing radiological

criteria, by developing engineering options and conducting appropriate National Environmental Policy Act reviews; (3) to carry out the selected remedial action; and (4) to certify completion of the remedial action consistent with existing radiological criteria.

The major problem areas are: (1) formerly utilized sites remedial action program (FUSRAP); (2) remedial action at Grand Junction, Colorado (P.L. 92-314, as amended); (3) uranium mill tailings remedial action program (UMTRAP) for inactive uranium mill tailings (P.L. 95-604); (4) management of certain radioactively contaminated Department facilities declared surplus and resulting principally from civilian nuclear energy programs; and (5) demonstration of the solidification of high-level radioactive wastes at West Valley for final disposal (P.L. 96-368).

Potential Areas for New Research

- Development of new decontamination and decommissioning techniques for contaminated facilities and sites.
- Development of new methods for determining radioactive nuclide transport through various media.
- Development of containment techniques for inactive uranium mill tailings sites to assure no radioactive migration.
- Development of remote sluicing techniques for removal of highly radioactive clay-like sludge from the bottom of High-Level Waste storage tanks.

Program Information Contact

Remedial Actions
John E. Baublitz (301) 353-5272
(all except West Valley)

West Valley Demonstration Project
James A. Turi (301) 353-5241

Uranium Enrichment Activities

Program Objectives

The major objective of the Uranium Enrichment Program is to meet the domestic, foreign, and U.S. Government requirements for uranium enrichment services in the most economical, reliable, safe, and environmentally acceptable manner possible.

To assure that this objective continues to be met, the Department of Energy supports development programs to provide cost effective alternatives for replacing existing enriched uranium production capacity by the mid-1990's. Two processes have the potential to meet this criterion and are being actively considered. They are: (1) gas centrifuge separation based on advanced designs, and (2) the Atomic Vapor Laser Isotope Separation technique, which employs finely-tuned, red-orange laser light to separate the uranium isotopes. Research initiatives in the uranium enrichment technical area would focus on, but would not be limited to, projects which would be directly applicable to either development program.

Potential Areas for New Research Initiatives

- Advanced concepts in isotope separation;
- Visible laser electro-optic subsystem and component development;
- Uranium materials science.

Program Information Contact

Uranium Enrichment Activities
Norton Haberman (301) 353-4781

Water Cooled Breeder

Program Objective

The Water Cooled Breeder Program's objective is to develop technology for significantly improving nuclear fuel resource utilization by water cooled nuclear reactors used for electrical power generation. The concept currently under development is a self-sustained breeder reactor cooled and moderated with light water. Successful development of this breeder cycle, including confirmation of breeding, can provide the basic technology to make available for power production about 50 percent of the nation's thorium reserves, a source of energy many times greater than the known fossil fuel reserves.

Potential Areas for New Research Initiatives

Further development of the technologies required for a light water breeder reactor.

Program Information Contact

Water Cooled Breeder
Nicholas R. Schact (703) 557-5550

Program Dedicated Facilities

Bettis Atomic Power Laboratory
Post Office Box 79
West Mifflin, Pennsylvania 15122

A.C. Davis
General Manager
Telephone Number (412) 462-5000, x0200

Richard A. Guida
General University Activities Contact
Telephone Number (703) 557-5564

The Bettis Atomic Power Laboratory is devoted exclusively to the Naval Nuclear Propulsion Program and includes three sites. The principal one, the Bettis Site, performs research and development of naval nuclear propulsion plants and carries out the Water Cooled Breeder program. The Shippingport Atomic Power Station, the first commercial nuclear power station, presently contains a Light Water Breeder Reactor. Operated by the Duquesne Light Company, this unique reactor produced electricity for the commercial power grid and is now being defueled. The third site, the Naval Reactors Facility, is located within the Idaho National Engineering Laboratory site. This installation operates three prototype naval reactor plants and a facility for examination of naval reactor cores.

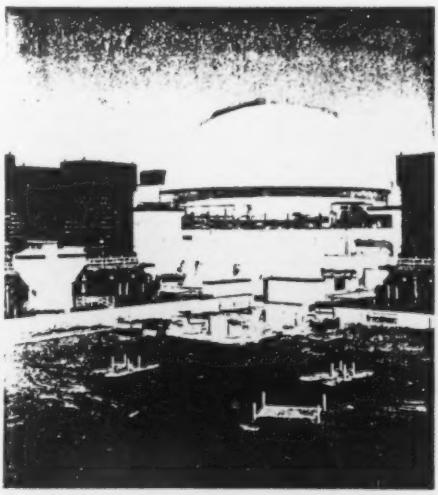
Energy Technology Engineering Center
Post Office Box 1449
Canoga Park, California 91304

H.C. Wieseneck
Vice President and General Manager
Telephone Number: (213) 700-5326

The Energy Technology Engineering Center (ETEC) provides management, engineering, testing, consultation and project monitoring services for a wide range of Department of Energy (DOE) programs. ETEC tests components being developed for the U.S. fast breeder reactor program. Liquid-sodium test facilities are maintained and operated by ETEC for evaluating components such as heat exchangers, steam generators, pumps, valves, piping and instrumentation. In addition to the reactor component testing program, ETEC provides engineering support, technical management and monitoring for a variety of DOE solar heating, cooling and power projects, geothermal power plants and direct use applications, and fossil energy fuel conversion programs.

Hanford Engineering Development Laboratory
Post Office Box 1970
Richland, Washington 99352

John E. Nolan
Director
Telephone Number (509) 376-3915



Fred J. Leitz
General University Activities Contact
Telephone Number (509) 376-3110

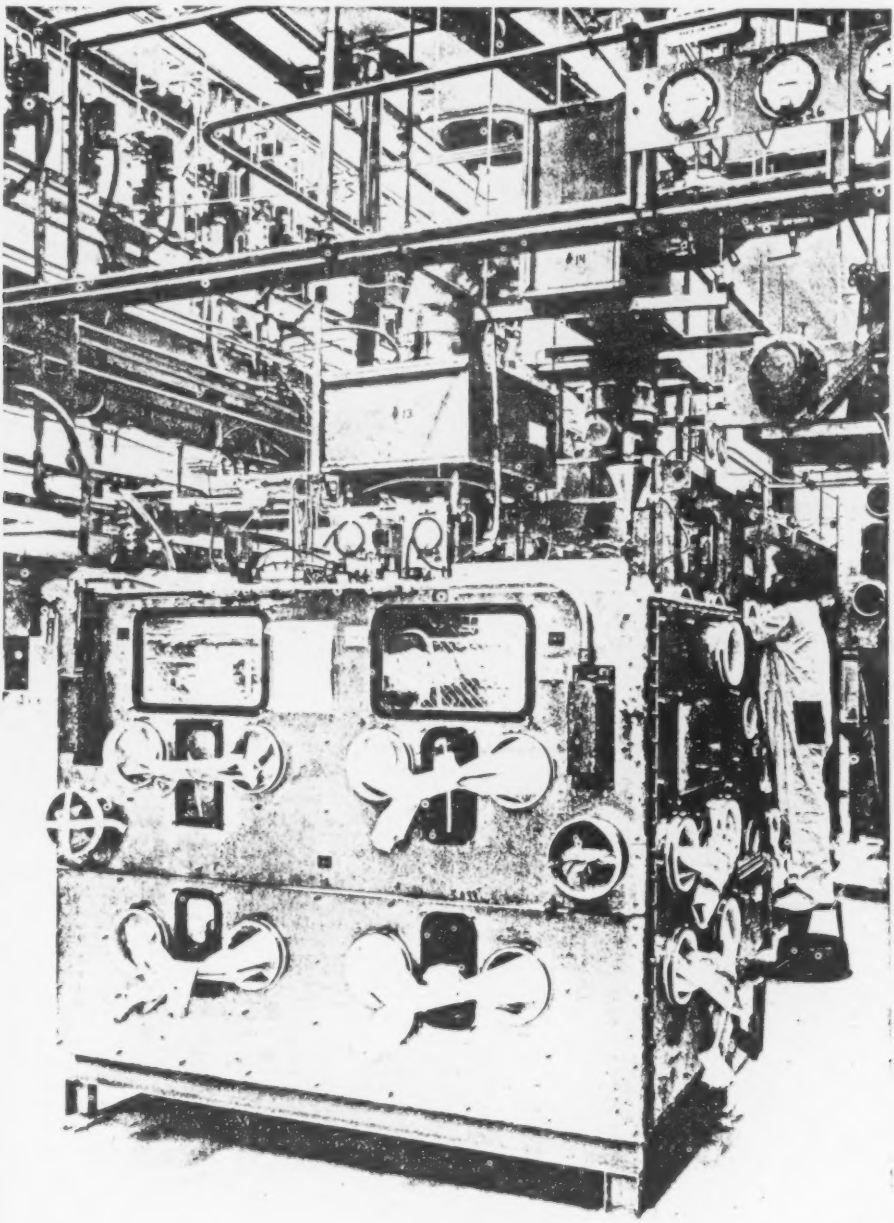
The Hanford Engineering Development Laboratory (HEDL) is committed to the development of breeder reactor fuels, materials research, and the development of advanced nuclear power concepts. The 400 MW Fast Flux Test Facility is the most advanced test reactor in the country and is the major HEDL test bed for breeder reactor development. The special materials expertise of the laboratory is also being utilized to support development of special reactor materials for the fusion program. The Fusion Materials Irradiation Test facility is being designed and constructed to support this effort.

Knolls Atomic Power Laboratory
U.S. Department of Energy
Post Office Box 1072
Schenectady, New York 12301

A.E. Kakretz
General Manager
Telephone Number (518) 393-6611, x4200

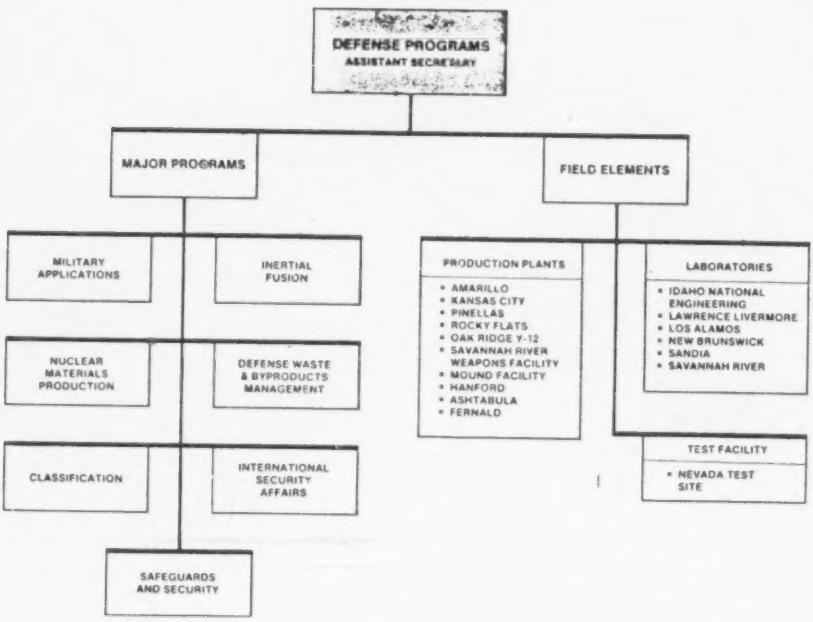
Richard A. Guida
General University Activities Contact
Telephone Number (703) 557-5564

The Knolls Atomic Power Laboratory (KAPL) is devoted exclusively to the Naval Nuclear Propulsion Program, and includes a three sites. The principal one, the Knolls Site, performs research and development of naval nuclear propulsion plants. Also in Schenectady, the Kesselring Site is the location for four prototype plants. The Windsor Site, in Windsor, Connecticut, is the location of a fifth prototype.



57

Defense Programs



Assistant Secretary for Defense Programs

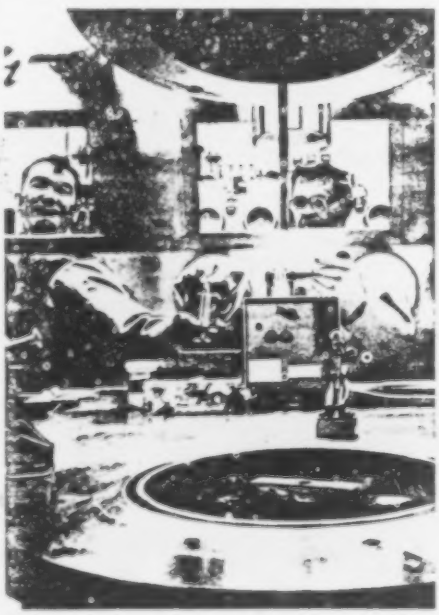
General Description

The Assistant Secretary for Defense Programs manages Department of Energy programs for nuclear weapons research, development, testing, production and surveillance; laser, heavy ion, and particle beam fusion; safeguards and security programs; the international security program; and classification. In addition, the office is responsible for the nuclear materials production and defense nuclear waste programs and exercises overview responsibility for the DOE weapons complex.

There are seven major program offices within Defense Programs. They are the Offices of Military Application, Inertial Fusion, Safeguards and Security, International Security Affairs, Nuclear Materials Production, Defense Waste and Byproducts Management, and Classification.

Field Elements

In addition to the major program offices, the Headquarter's Offices of Policy, Planning and Coordination and Resource Management serve as the DOE focal point on policy and institutional management of assigned field facilities. The Operations Offices play a significant role in the development, production or testing of nuclear weapons. Los Alamos, Lawrence Livermore, and Sandia Laboratories are involved in varying degrees in support of all facets of the weapons program, i.e., design, engineering, test production, and surveillance. The New Brunswick Laboratory supports the security and safeguards program; Savannah River Laboratory is specifically involved in production of nuclear materials. The Mound and Savannah River Weapons Facilities, Amarillo, Kansas City, Pinellas, Rocky Flats, and Y-12 Plants are engaged in the weapons production program. The Savannah River, Hanford, Ashtabula, Fernald and Idaho Chemical Processing Plants constitute a major part of the DOE Nuclear Materials Production Program. The Nevada Test Site is reserved for nuclear test operations.



Proposal Review Procedures

In general, after a proposal has been received in the Office of Defense Programs and has been logged into the DOE procurement system, the proposals are assigned to a field office for technical evaluation. The evaluation and budget constraints determine whether the proposal is accepted or declined. If accepted, the normal administrative process for contract negotiations takes about six months.

The Office of Inertial Fusion, Defense Programs, however, uses a variation of this procedure. Unsolicited proposals intended for review by the Office of Inertial Fusion should be submitted directly to the Nevada Operations Office as follows:

Mr. Rex Purcell
U.S. Department of Energy
Nevada Operations Office
Post Office Box 14100
Las Vegas, Nevada 89114
Telephone: (702) 295-0969

The Nevada Operations Office accepts the proposals and determines which lead laboratory should provide a technical review. The proposal is sent to the appropriate laboratory for technical review and a recommendation is made as to whether or not the proposal has technical merit. The Nevada Operations Office makes a decision based on that recommendation, and other factors (such as program priorities and availability of funds). If a proposal is accepted, the Nevada Operations Office negotiates, awards, and administers the necessary Inertial Fusion Program contract. Technical monitoring is provided by the cognizant lead laboratory.

Program Information Contact

General Information
A. Bryan Siebert (301) 353-4227

Defense Waste and Byproducts Management

Program Objectives
The objective of the defense nuclear waste management program is to assure that existing and future nuclear waste from DOE program activities can be isolated from the biosphere and pose no significant threat to public health and safety. To implement this objective, the DOE program focuses on the development of technology and the processes necessary for long-term disposal. This program also provides for the decontamination and decommissioning of facilities that are surplus to DOE activities.

Potential Areas for New Research Initiatives

Transuranic Waste
- Mechanism(s) for immobilizing transuranic waste (TRU) elements.
- Modeling TRU element leaching from waste.
- Rate modeling for accelerated leach testing. (Short-term test to predict long-term TRU leach rate behavior).

High-Level Waste
- Waste form performance in a repository including mechanisms for immobilizing high-level waste.
- Radiation damage.
- The mechanism(s) of glass leaching.
- Fracture behavior of nuclear waste forms e.g., glass.
- Devitrification behavior in glass.

Byproducts and Beneficial Uses
- Food preservation/disinfestation by irradiation
- Human factors regarding use of tritium and krypton lights

Low-Level Waste
- Improving stabilization of shallow land burial grounds used in disposal of low-level radioactive wastes

Program Information Contact
Defense Waste and Byproducts Management
James C. Landers (301) 353-3506

Inertial Fusion

Program Objective
As part of the weapons program effort, the goal of the inertial fusion program is to determine the potential of inertial fusion for application to weapons technology and to energy production. The next major objective of the technical program to accomplish this goal is to understand driver/target interactions in the range of driver energies obtainable with the following experimental facilities now being built:
- ANTARES carbon dioxide laser at Los Alamos National Laboratory, Los Alamos, New Mexico;
- NOVA glass laser system at Lawrence Livermore National Laboratory, Livermore, California;
- Particle Beam Fusion Accelerator (PBFA) II at Sandia National Laboratories, Albuquerque, New Mexico.

National Laser Users Facility
The University of Rochester operates the National Laser Users Facility at which experiments in inertial fusion or other scientific fields can be performed by university, industrial, or government research teams. The DOE encourages anyone interested in conducting an experiment at the National Laser Users Facility to forward proposals to:

Mr. Rex Purcell
U.S. Department of Energy
Nevada Operations Office
Post Office Box 14100
Las Vegas, Nevada 89114
Telephone: (702) 295-0969

Additional information on the National Laser Users Facility may be requested from:

Dr. Tom Bristow
Executive Secretary
National Laser Users Facility
University of Rochester
Laboratory for Laser Energetics
250 East River Road
Rochester, New York 14623
Telephone: (716) 275-2074

or from the *User's Guide to DOE Facilities* (DOE/ER-0174).

Problem Areas Requiring Additional Research
- Laser/matter interaction;
- Particle beam generation and transport;
- Plasma diagnostics; and
- Target fabrication

Program Information Contact
Inertial Fusion
Dr. R.L. Schriever (301) 353-3463

Reference
User's Guide to DOE Facilities (DOE/ER-0174)

Military Applications

Program Objectives

The overall objectives for the weapons program are to:

1. Insure adequate and timely nuclear weapon design options for national security;
2. Produce new nuclear weapons as requested by the Department of Defense and approved by the President;
3. Provide lifetime surveillance and maintenance of the existing weapons stockpile to assure a constant state of high readiness and reliability; and
4. Advance and transfer technology applicable to other national security and energy programs.

The highly complex and classified nature of the weapons program mission precludes any further expansion of direct university involvement in the program beyond the levels currently projected. However, the major operating contractors involved in the program do support subcontract efforts at universities consistent with program priorities, university capabilities, and funding availabilities.

Program Information Contact
Military Applications
Bruce A. Cooper (301) 353-3374

Nuclear Materials Production

Program Objectives

The goal of the Materials Production program is to provide nuclear materials to meet near-term national defense and nondefense requirements in a safe, environmentally acceptable manner. In addition, Materials Production sustains a base production program capable of meeting long-term nuclear materials production requirements consistent with the annual Presidential Nuclear Weapons Stockpile Memorandum and the annual DOE Materials Management Plan.

Potential Areas of Research Initiatives

- Processing of nuclear materials
- Decision support system
- Robotics for remote operations
- Special isotopes separation
- Assessment of the impacts of plant operations on the environment
- Reactor safety

Program Information Contact
Nuclear Materials Production
Robert J. Galbo (301) 353-3982

Safeguards and Security

Program Objective

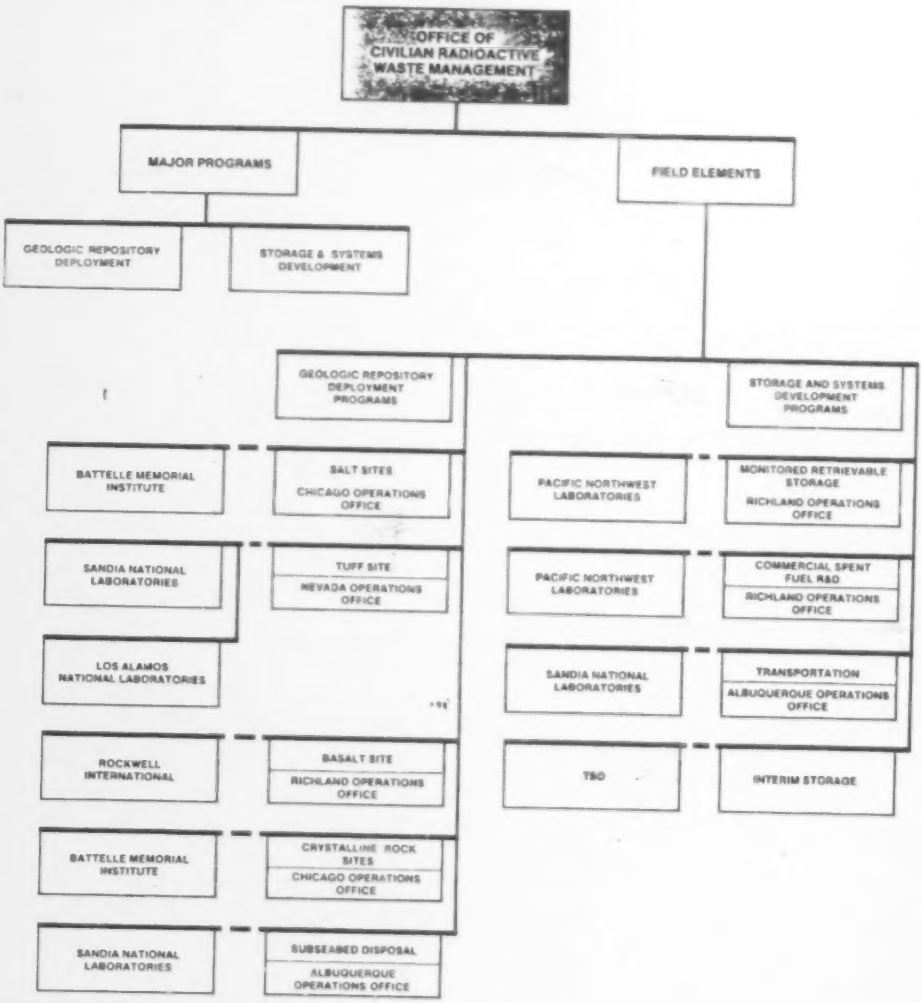
The Office of Safeguards and Security is responsible for coordination of DOE safeguards and security efforts to protect special nuclear materials, nuclear weapons, all classified activities, and DOE facilities. The Office develops, tests, evaluates and assists in the implementation of safeguards systems that incorporate physical protection, material control and material accountability into facility-wide integrated safeguards systems for each installation. The New Brunswick Laboratory supports this office through research on the security and safeguards of nuclear materials.

Potential Areas of Research Initiatives

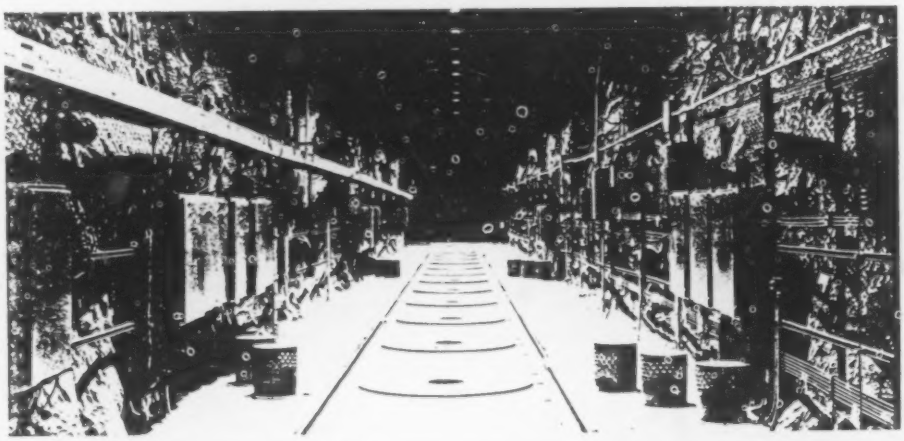
- Safeguards activities;
- Security activities;
- Technology activities; and
- International activities.

Program Information Contact
Safeguards and Security
Nelson C. Marsh (301) 353-5690

Civilian Radioactive Waste Management



Office of Civilian Radioactive Waste Management



General Description
Section 304(a) of the Nuclear Waste Policy Act of 1982, P.L. 97-425, establishes within the Department of Energy an Office of Civilian Radioactive Waste Management (OCRWM) to focus on research and development leading to the disposal of radioactive wastes. Major responsibilities of the office include: geologic repository activities; storage and systems development activities; and general management and support of the programs and their relationships with other institutions.

The Director of OCRWM provides overall policy recommendations to the Secretary and policy guidance to all elements of the office including to the field project offices.

Field Elements
OCRWM provides policy guidance, general program direction, and overall technical review for the major programs, while field project offices and contractors (as illustrated on the preceding page under "Field Elements") are responsible for the execution of programs and management of specific projects.

Proposal Review Procedures

- **Unsolicited Proposals**
  Proposals submitted to DOE are logged in at a central point in the DOE Headquarters Procurement Office. A written technical evaluation is prepared by the cognizant program office representative and, on the basis of the evaluation, negotiations are initiated or the proposal is officially rejected. Technical work efforts may also be proposed directly to the major technical management center contractor.

Program Information Contact
General Information
Robert Rosselli (202) 252-6842 or (301) 353-4808

Geologic Repository Deployment

Program Objectives
The long-term goal of the geologic repository activity is the construction of one or more repositories for the permanent disposal of high-level radioactive waste and spent nuclear fuel in a manner that fully protects the public health/safety and the environment.*

The principal functions of this program are to locate, design, construct, operate, and decommission radioactive waste disposal facilities. The program is responsible for screening and characterizing potential geologic repository sites; recommending sites; conducting in-situ tests within exploratory shafts; designing a test and evaluation facility; and managing the R&D of disposal technology for both repositories.

Subseabed disposal is the only alternative means of disposal to mined geologic repositories currently being funded by DOE. This method is being undertaken as a national and international enterprise. The major objectives of this activity are to determine the feasibility of burying high-level radioactive waste in stable clay sediments of the deep ocean; cooperate with other nations in the

assessment of subseabed disposal; and, if the concept proves feasible, retain this as an alternative method of nuclear waste disposal.

Potential Areas for New Research Initiatives

- Sorption of radionuclides on geologic media;
- Leaching of waste forms in ground waters;
- Interactions among materials of the waste package, host rocks, and ground waters;
- Fracture flow in geologic media;
- Radiation effects on repository containment;
- Solubility of radionuclides in ground waters;
- Flow and transport in unsaturated media;
- Measurement of hydrologic parameters in low permeability rocks;
- Reliability of stress measurements under expected repository conditions;
- Radiation effects on deep-sea organisms;
- Development of deep ocean monitoring techniques to measure radionuclide transport and chemical effects in sediments; and
- Identification and characterization of the life cycle of mid-water organisms (below 1000 meters).

Program Information Contact
Geologic Repository Deployment
J. William Bennett (301) 353-4286

*The reader should also note that longer-range research relative to nuclear waste isolation is supported in the Basic Energy Sciences Program of the Office of Energy Research.

Storage and Systems Development

Program Objectives

The role of the Office of Storage and Systems Development is to implement both interim and long-term storage activities. The program is responsible for waste packaging, handling, transportation and storage technologies, equipment, and facilities for radioactive waste. Major project activities include: monitored retrievable storage (MRS) facilities for long-term storage as a backup capability for mined geologic repositories; conducting international cooperation programs; evaluating integrated systems for packaging and transportation of radioactive wastes; and providing Federal interim storage (FIS) facilities, if needed. The Office also encourages, through a joint demonstration program and R&D efforts, civilian "at-reactor" storage of spent nuclear fuel and assists in licensing various storage options.

The major objectives of this effort are:

- To assure that a safe, environmentally acceptable, and cost-effective transportation system is available to support each of the activities or facilities called for by the Nuclear Waste Policy Act;
- To maximize the efficiency and flexibility of operations required to manage nuclear waste from any of its sources to the final repository;
- To encourage and expedite the efficient use of existing storage facilities and the addition of new "at-reactor" capacity through:
  - — A cooperative demonstration program with the private sector to demonstrate spent fuel rod consolidation in existing water basins;
  - — A cooperative demonstration program with the private sector to develop dry storage technologies that NRC can generically approve;
  - — Consultative and technical assistance to utilities on a cost-shared basis in anticipation of NRC licensing of on-site storage technologies; and

Potential Area for New Research Initiatives
None

Program Information Contact
Storage and Systems Development
Robert Bauer (202) 252-6842

Energy Information Administration

General Information

The Energy Information Administration (EIA) develops and maintains a credible and consistent base of energy information which is made available to the Executive Branch, Congress, state governments, industry and the general public. EIA provides energy data, analysis, and information processing support to the other Department of Energy offices, prepares energy analysis and projections on a regularly scheduled basis (as well as for special purposes) and supports Departmental contingency planning and emergency operations.

EIA also maintains the National Energy Information Center (NEIC). The NEIC edits manuscripts and prepares graphics for EIA publications and distributes all EIA products. These products include: data publications, interpretive reports, information directories, computer tapes for public use, microfiche, and EIA press releases/fact sheets. The NEIC also manages the EIA "Family of Publications" program, under which EIA publications are classified and designed according to energy source and metadata groupings. In 1983, NEIC answered more than 75,000 inquiries about energy matters, about half of them from the business community.

Program Information Contacts
Energy Information Administration
Judith Tishman (202) 202-6537
National Energy Information Center-Director
John E. Daniels (202) 252-2363
General Information Services
NEIC (202) 252-8800

References
1. Energy Information Directory—Second Half 1983 (DOE/EIA-0205(83/2)
2. EIA Publications—New Releases (DOE/EIA-0204(84/01)

Office of Minority Economic Impact

General Information

The Director of the Office of Minority Economic Impact advises the Secretary on the effects of energy policies, regulations and other actions of the Department and its components on minorities, minority business enterprises and minority educational institutions; on ways to ensure that minorities are afforded the opportunity to participate fully in energy programs of the Department; and on the implementation of the Department's support of research and related programs for the Historically Black Colleges and Universities pursuant to Executive Order 12320.

In carrying out these responsibilities, the Office formulates and manages a research program with the assistance of the Energy Information Administration and other Federal agencies, as appropriate. Such research is focused on determining the effects, including the socio-economic and environmental impact of national energy programs and policies on minorities. The research evaluates and analyzes data to determine minority energy consumption and usage patterns, and evaluates the percentage of disposable income spent by minorities on energy compared to national usage patterns, identifies how programs, policies and actions of the Department effect minority energy consumption and usage patterns.

and determines employment potential and minority business opportunities for minorities in specific segments of the energy industry.

The Office formulates programs to provide management, technical, and financial assistance to minority businesses, educational institutions, and development organizations to enable them to participate in the Department's research or other program activities; and to establish or expand energy-related business opportunities in minority communities. The Office also provides outreach and liaison to minority educational institutions to provide them with information on the Department's programs, policies, and research activities.

It should also be noted that the Office of Minority Economic Impact, pursuant to Section 211(e)(1) of Public Law 95-619 and 10 CFR Part 800, has authority to issue loans to minority business enterprises to assist them by financing up to 75 percent of the costs incurred in preparing bids or proposals seeking DOE contracts or assistance. Information regarding loan availability, eligibility criteria, and application procedures may be obtained from:

San Francisco Operations Office, USDOE
1333 Broadway
Oakland, California 94612
Attn: Grants and Loan Division
Phone: (415) 273-4461

Program Information Contact
Office of Minority Economic Impact
Elmer Lee (202) 252-8383

Office of Small and Disadvantaged Business Utilization (OSDBU)

General Information

The Office of Small and Disadvantaged Business Utilization is responsible for policy, plans and oversight for execution of DOE functions relating to preference programs for small businesses, minority businesses, other businesses owned by disadvantaged persons, women-owned businesses and labor surplus area firms. The Office provides functional supervision and oversight of DOE personnel as they perform duties relating to these programs. The programs are DOE-wide and are achieved under the executive direction of the Secretary and in functional coordination with the Director of Procurement and Assistance Management.

Some of the specific functions of the Office are:

- Formulates, recommends and monitors implementation of policy for the Department's small business program, disadvantaged business program, women-owned business program, and the labor surplus area.
- Ensures effective implementation of the Department's goals and plans for the preference programs and monitors the activities of the Department's buying offices relating to such plans.
- Ensures that all contracts, solicitations, and subcontracts over $500,000 (or $1 million for public facility construction) include the mandatory plans, goals and/or clauses, unless exempted by law.
- Coordinates the preparation of and recommends Secretarial approval of DOE goals in small, disadvantaged, women-owned business enterprises and labor surplus area business utilization.
- Establishes and maintains outreach liaison contacts with the small business, disadvantaged business and women-owned business communities to provide a flow of information regarding the DOE socio-economic procurement programs and to encourage participation in those programs.
- Reviews, evaluates and reports to the Secretary on the performance of all DOE organizational units in accomplishing preference program procurement goals.
- Counsels small business, disadvantaged business, labor surplus area and women-owned business firms on doing business with DOE.
- Provides necessary support to the Program Manager for the Small Business Innovation Research Program.

Program Information Contact

Office of Small and Disadvantages Business Utilization (OSDBU)

John W. Shepard (202) 252-8201

Richland Operations Office
Richland, Washington
Idaho Operations Office
Idaho Falls, Idaho
San Francisco Operations Office
Oakland, California
Nevada Operations Office
Las Vegas, Nevada
Albuquerque Operations Office
Albuquerque, New Mexico
Chicago Operations Office
Argonne, Illinois
Oak Ridge Operations Office
Oak Ridge, Tennessee
Savannah River Operations Office
Aiken, South Carolina

Part II.
Operations Offices

Albuquerque Operations Office
Post Office Box 5400
Albuquerque, New Mexico 87115

Raymond G. Romatowski
Manager
Telephone Number (505) 844-7231

Dennis Krenz
General University Activities Contact
Telephone Number (505) 846-5203

National security is the principal mission of the Albuquerque Operations Office (AL) which operates an extensive weapons laboratory and production complex from Florida to California; supervises six area and two support offices; administers two National Laboratories, (Los Alamos National Laboratory and Sandia National Laboratories) five weapons production plants (Rocky Flats, Pinellas, Pantex, Kansas City and Mound), the weapons production facilities at Oak Ridge and Savannah River, and the operation of the Inhalation Toxicology Research Institute, Ross Aviation, and the National Atomic Museum on Kirtland Air Force Base-East at Albuquerque. Major assignments include field coordination and direction of weapons research, development and production; organization and operation of a system for safe-secure transport of all government-owned special nuclear material of strategic quantities; program execution and project management associated with assigned energy research, development and demonstration activities; coordination and administration of nuclear test detection activities; reimbursable assistance to local, state, Federal and foreign governments and the private sector; maintenance of radiological assistance, nuclear weapons accident response capabilities; administration of waste isolation pilot plant project and the uranium mill tailings remedial actions project; and establishment of working relationships with many state, university and regional energy organizations.

Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois 60439

Hilary J. Rauch
Manager
Telephone Number (312) 972-2110

Jane L. Monhart
General University Activities Contact
Telephone Number (312) 972-2089

The Chicago Operations Office (CH) was intimately involved in the design, engineering, and construction of nuclear power facilities in the 1950's and 1960's as well as the development and demonstration of new energy technologies. CH manages the operations and institutional resources of a broad range of multi-program and single purpose facilities. It also provides acquisitions and assistance, engineering, and other technical support for program and project managers in Headquarters and independently manages assigned projects and energy research and development programs.

Current Chicago Operations assignments include key elements of the liquid metal fast breeder reactor (LMFBR) base technology program, the salt and crystalline rock projects in the Civilian Nuclear Waste Management Program, magnetic confinement fusion R&D and test facility activities, magnetohydrodynamic projects and test facility activities, conservation and renewable energy technology projects, and monitoring of the Federal loan guarantee for the Great Plains Coal Gasification Project.

Laboratories and facilities managed by the Chicago Operations Office include: Argonne National Laboratory, Brookhaven National Laboratory, Ames Laboratory, Princeton Plasma Physics Laboratory, Fermi National Accelerator Laboratory, Bates Linear Accelerator Facility, Environmental Measurements Laboratory, New Brunswick Laboratory, Notre Dame Radiation Laboratory, Radiobiology Laboratory at the University of Utah, Michigan State University (MSU)/DOE Plant Research Laboratory, University of Rochester Biomedical Laboratory and the Solar Energy Research Institute. CH also administers and manages financial instruments in over 200 universities and more than 500 businesses, industries, non-profit organizations, and state and local governments.

Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Troy E. Wade II
Manager
Telephone Number (208) 526-1322

Charles E. Gilmore
General University Activities Contact
Telephone Number (208) 526-1808

The Idaho Operations Office (ID) was established to administer the National Reactor Testing Station, an isolated site for testing various nuclear reactors and for associated support facilities. The site was renamed Idaho National Engineering Laboratory (INEL) in 1974 to better reflect the engineering and development assignments and expanding operations of nuclear and nonnuclear energy programs. INEL's principal mission is to support DOE in its defense-related nuclear materials production and

nuclear waste management programs. Additionally, INEL works to develop economic energy resources by applying engineering and scientific expertise to the agency's research and development programs which include nuclear energy, geothermal and advanced energy sources, environment and safety, and national security applications. ID is responsible at the INEL for operating the Radiological and Environmental Sciences Laboratory, which provides chemistry, dosimetry and environmental monitoring for all on-site activities; supporting the Nuclear Regulatory Commission's Region IV Office of Inspection and Enforcement Division; and administering the National Environmental Research Park. In addition, ID staff are located in Butte, Montana (administering the Magnetohydrodynamic Component Development and Integration Facility); in Grand Junction, Colorado (administering the Remedial Action Program involving mill tailings and support for the National Waste Storage Program); in Denver, Colorado (administering awards and grants in programs such as the state and local energy conservation programs); in West Valley, New York, (administering the Remedial Action Program at West Valley); and in Harrisburg, Pennsylvania, Three Mile Island Site Office (administering INEL's support role in cleanup of the Three Mile Island Unit-2 accident).

Nevada Operations Office
P.O. Box 14100
Las Vegas, Nevada 89114

Thomas R. Clark
Manager
Telephone Number (702) 295-3211

David F. Miller
General University Activities Contact
Telephone Number (702) 295-3521

The Nevada Operations Office (NV) was established by the U.S. Atomic Energy Commission and assumed responsibilities for programs at the Nevada Test Site (NTS). The NTS, located 65 miles northwest of Las Vegas, was chosen as a continental proving ground in 1950 to reduce the expense and logistic problems of testing in the Pacific. It is an integral part of NV and does not operate as a separate entity. The primary mission of NTS is to provide a remote, secure facility for the safe conduct of underground nuclear testing in support of national defense programs. Over the years of operation at NTS, NV contractors have developed unique expertise in such fields as drilling, mining, and down-hole diagnostics in support of the weapons development laboratories and the Department of Defense. Additionally, use of the site has been expanded to include many other programs and projects, for example: waste mangement; biological and medical experiments to study plant and animal life in a radiation environment; geologic, hydrologic, and seismic investigations; and development of applications of nuclear explosives in science and industry.

NV is responsible for conducting all U.S. nuclear tests. Other program responsibilities assumed by NV and its contractors include maintaining a readiness base at Johnston Island to resume testing in the Pacific Ocean area, development of geothermal and hydrocarbon natural resources, fuel conservation, and program and contract management of various programs assigned by Headquarters.

Oak Ridge Operations Office
P.O. Box E
Oak Ridge, Tennessee 37380

Joe LaGrone
Manager
Telephone Number (615) 576-4444

William A. Mynatt
General University Activities Contact
Telephone Number (615) 576-0651

The Oak Ridge Operations Office (OR) was originally established under the U.S. Atomic Energy Commission during the Manhattan Project of World War II. Major programs and projects at Oak Ridge Operations Office are the production of nuclear weapon components in support of national defense programs; the production of enriched uranium for defense requirements and for fueling nuclear power plants in the U.S. and abroad (the enriching capacity is being expanded at present, both by the upgrade of the gaseous diffusion process and the development of gas centrifuge and laser isotope separation technologies); the processing of uranium feed materials and related production of uranium fuel cores for the Agency's plutonium production reactors; management of the Department's Strategic Petroleum Reserve; closeout of the Clinch River Breeder Reactor Project; and extensive energy research and development. OR administers the Oak Ridge National Laboratory; Oak Ridge Associated Universities; the Ashtabula Extrusion, Fernald Feed Materials and Y-12 Plants; Oak Ridge, Paducah and Portsmouth Gaseous Diffusion Plants; and the Center for Energy and Environment Research located at the University of Puerto Rico.

Richland Operations Office
P.O. Box 550
Richland, Washington 99352

Alex G. Fremling
Manager
Telephone Number (509) 376-7395

B.J. Melton
General University Activities Contact
Telephone Number (509) 376-7378

The Richland Operations Office (RL) was established as the Manhattan Project Plutonium Production Facility. RL is responsible for: management of the 570-square mile Hanford Site, at which a broad range of nuclear and nonnuclear energy programs are conducted under all agency program Secretarial Offices; continuing operation of nuclear production, chemical processing and waste management programs, including interim storage and ultimate disposition of high-level radioactive wastes; management of advanced reactor development programs; providing program management and overview, budgetary

direction, contract management, and administrative and policy guidance to eight operating and support service contractors; and management of facilities (Hanford Engineering Development Laboratory, Pacific Northwest Laboratory and Hanford Production Operations) and site services. RL supports the local Joint Center for Graduate Study, which provides educational opportunities to agency and contractor staff; contracts with NORCUS, a consortium of about 50 universities which administers a University-Laboratory Cooperative program; participates in the Used Energy-Related Equipment Grant program for universities; and contracts for energy-related research at all major northwestern universities.

San Francisco Operations Office
1333 Broadway
Wells Fargo Building
Oakland, California 94612

Richard A. Du Val
Manager
Telephone Number (415) 273-7111

Richard H. Nolan
General University Activities Contact
Telephone Number (415) 273-6419

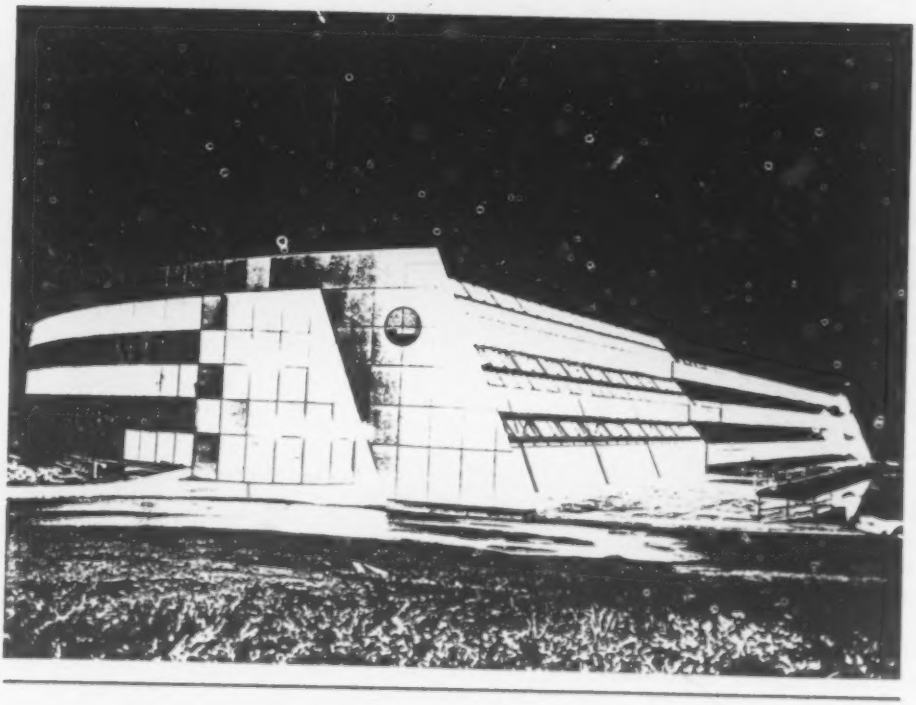
The mission of the San Francisco Operations Office (SAN) is to execute defense and energy-related programs and to provide input to program development and policy formulation. SAN is responsible for the management, coordination, and support of programs and projects involving weapons research and development, basic research, and R&D in all energy technologies. This includes the administration of the operation of seven laboratory and engineering facilities including two major national laboratories. These facilities are the Lawrence Berkeley Laboratory, the Lawrence Livermore National Laboratory, Stanford Linear Accelerator Center, the Energy Technology Engineering Center, Laboratory for Energy-Related Health Research, Laboratory of Biomedical and Environmental Sciences and the Laboratory of Radiobiology and Environmental Health. Field construction management of major technical facilities is another primary functional responsibility. Examples of major projects include the Mirror Fusion Test Facility, designed to test the Tandem Mirror fusion concept, and the NOVA High Energy Laser Facility for weapons physics and fusion energy research.

Savannah River Operations Office
P.O. Box A
Aiken, South Carolina 29801

Goetz Oertel
Manager
Telephone Number (803) 725-2277

Robert A. McFeely
General University Activities Contact
Telephone Number (803) 725-2841

The Savannah River Operations Office (SR) is one of the key installations in the special nuclear materials production and research program in the Department, responsible for production of nuclear materials for national defense, and related environmental research activities. It is responsible for design, construction, operation, and maintenance of a multibillion dollar industrial facility; the program for immobilization and subsequent permanent storage of Savannah River Plant's high-level, liquid radioactive waste; continuing high-level radiological waste management; design, construction and operation of a facility to provide a second source of fuel materials for Naval Nuclear Propulsion Systems; nuclear production reactor operation and safety; chemical reprocessing technology; and studies of the environmental effects of nuclear and industrial operations. The entire site (300 square miles) was designated as the Nation's first National Environmental Research Park in 1972. The laboratories and plants administered by the Savannah River Operations Office are the Savannah River Laboratory, the Savannah River Ecology Laboratory, the Savannah River Plant, the Savannah River Weapons Facility and the Savannah River Forest Station.



Part III
Field Laboratories

Multiprogram Laboratories

The multiprogram laboratories conduct high quality, nationally important basic research and applied research and development that, because of its nature, is more appropriately undertaken by a Federal laboratory than by universities or industry. In fundamental research, the laboratories, therefore, focus on scientific areas of excellence that require large, capital-intensive experimental facilities, or that need sustained effort over periods of many years. In applied research, the focus is on nuclear weapons and defense-related activities, development of energy technologies involving large uncertainties and lead times, or important energy-related environmental factors. The laboratories also maintain for the Government the capability to provide independent scientific advice in their areas of expertise.

These responsibilities require the maintenance of broad multidisciplinary scientific capabilities in the laboratories and the conduct of research and development supporting a technology base appropriate to each laboratory's missions. These capabilities are applied to national problems that are generally between the interests and capabilities of both the university and industrial sectors, and that are of sufficient importance, size, term, and complexity to benefit from and effectively use the laboratories' unique mix of skills and facilities. The laboratories also work with the scientific and technical community, where feasible and beneficial, to achieve effective utilization of their unique research facilities, to aid in education of scientists and engineers, and to enhance the transfer of technology to the public and private sectors.

In all, there are nine DOE multiprogram laboratories. The primary mission of the three weapons laboratories (Lawrence Livermore, Los Alamos and Sandia) is focused on national security. The six other laboratories carry out research and development for all DOE programs (Argonne, Brookhaven, Idaho, Lawrence Berkeley, Oak Ridge, and Pacific Northwest). Each of the multiprogram laboratories is discussed briefly in the following paragraphs. For more detailed information regarding the research facilities at the multiprogram laboratories, also refer to *DOE Research and Development Field Facilities* (DOE/ER-0029) and/or the *User's Guide to DOE Facilities* (DOE/ER-0174).

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Walter E. Massey
Director
Telephone Number (312) 972-5555

Robert W. Springer
General University Activities Contact
Telephone Number (312) 972-3374

Argonne National Laboratory (ANL) is operated for DOE by the University of Chicago under the administrative management of the Chicago Operations Office.

ANL provides advanced nuclear technology research and development support to the breeder and other advanced reactor programs, and maintains a substantial, diversified capability in physical and biological sciences. Work in nuclear fusion is focused on blanket technology and materials research. In basic research, a multidisciplinary effort in chemistry, nuclear physics, high energy physics and material research is carried out. Efforts in the fossil area center on advanced process development, the materials technology, and instrumentation and controls systems engineering.

Argonne National Laboratory sponsors a variety of programs providing opportunities for student-laboratory staff interaction and is a major participant in the Department's University/Laboratory Cooperative Program. ANL annually provides research appointments to faculty, graduate and undergraduate students for summer and academic year work in the basic physical and life sciences, mathematics, computer science, and engineering, as well as in a variety of applied research programs relating to coal, conservation, environmental impact and technology, fission, fusion and solar energy.

Brookhaven National Laboratory
Upton, New York 11973

Nicholas P. Samios
Director
Telephone Number (516) 282-2772

Glenn A. Price
General University Activities Contact
Telephone Number (516) 282-3336

Brookhaven National Laboratory (BNL) is operated for DOE by Associated Universities, Inc., under the administrative management of the Chicago Operations Office.

The major roles of the BNL are to conceive, construct and operate complex large research facilities, which are used to study the fundamental properties of matter and are shared with university and industrial communities (e.g. the National Synchrotron Light Source and the Alternating Gradient Synchrotron). Major disciplinary strength is found in the areas of high energy, nuclear and solid state physics, chemistry, and biology. Biological

and medical programs include studies of the effects of radiation and of chemical substances involved in the production and use of energy. Applied research programs are undertaken, often in conjunction with university or industrial cooperators, when the unique expertise or facilities available at the Laboratory are needed for the success of the mission.

Brookhaven's participation in the University Laboratory Cooperative Program focuses mainly on opportunities for highly qualified undergraduate students in such areas as the basic sciences, engineering, medicine and the environment. BNL also carries out a cooperative program with several Historically Black Colleges to help increase minority graduate study in the sciences and engineering.

Idaho National Engineering Laboratory
550 Second Street
Idaho Falls, Idaho 83401

Troy E. Wade II
Manager
Idaho Operations Office
Telephone Number (208) 526-1322

Charles E. Gilmore
General University Activities Contact
Telephone Number (208) 526-1808

Idaho National Engineering Laboratory (INEL) is operated for DOE by EG&G Idaho, Inc. and Westinghouse Idaho Nuclear Company, Inc., under the administrative management of the Idaho Operations Office.

Effort at this multiprogram laboratory is predominantly nuclear related. INEL missions include spent nuclear fuel reprocessing and recovery of nuclear fuel from several test reactors, the nuclear naval fleet, and other nuclear noncommercial type reactors, as well as processing of liquid waste into calcine form for intermediate storage; operations of a radioactive waste management complex for storage and disposal of low-level waste; investigating the safety of water cooled reactors, principally for the Nuclear Regulatory Commission; operations of the Advanced Test Reactor (ATR) and its experimental materials testing program; functioning as a primary laboratory for fusion reactor safety research; supporting DOE's non-nuclear energy research development programs such as geothermal and industrial conservation, utilizing the newly completed Idaho Laboratory Facility for non-nuclear research and testing; supporting priority defense and civilian nuclear power research and development efforts that are sited at the INEL but are the responsibility of other laboratories; supporting the Three Mile Island (TMI) Technical Information and examination program at the TMI reactor site and at INEL.

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

David A. Shirley
Director
Telephone Number (415) 486-5111

George L. Pappas
General University Activities Contact
Telephone Number (415) 486-5131

Lawrence Berkeley Laboratory (LBL) is operated for DOE by the University of California under the administrative management of the San Francisco Operations Office.

LBL conceives, develops, constructs and operates large, complex research facilities which are shared with university and industrial scientific communities (e.g., Bevalac and Super HILAC). The laboratory capitalizes on its co-location with the University of California to provide a broad range and flexible pool of scientific talent for research and advanced development; with major research programs in high-energy physics, nuclear physics, basic energy sciences, conservation and solar energy, coal research, inertial confinement fusion, geochemistry, computer science and mathematics.

Over 500 resident graduate students conduct thesis research at the Laboratory, and many more use LBL facilities or perform collaborative research. Participation in DOE-supported energy research programs at LBL provides these students with skills in high demand by energy industries.

Lawrence Livermore National Laboratory
Post Office Box 808
Livermore, California 94550

Roger E. Batzel
Director
Telephone Number (415) 422-7401

Mary E. Tuszka
General University Activities Contact
Telephone Number (415) 422-7933

The Lawrence Livermore National Laboratory (LLNL) is operated for DOE by the University of California under the administrative management of the San Francisco Operations Office.

The mission of LLNL is to function as a national resource of scientific and technical capability for the nation's nuclear weapons program and, as appropriate, for other programs of national interest. The Laboratory's primary role is to perform the research, development and testing associated with the nuclear design aspects of all phases of the nuclear weapon life cycle and perform associated national security related tasks. A corollary role is to address other important national problems meeting the following criteria: synergism with the weapons program; sufficient size, importance, and complexity to make effective use of significant or unique laboratory capabilities; and relative distinction from the research interests of the university and industrial sectors. Within this role the Laboratory has developed several areas of scientific and technical excellence and long-term commitment: inertial fusion, magnetic fusion, biomedical and environmental research, isotope separation, applied energy technology and other related research activities. Within these programs, LLNL interacts with both universities and private industry through faculty/student training and consulting and technology activities.

Los Alamos National Laboratory
Mail Stop A-100
Los Alamos, New Mexico 87545

Donald M. Kerr, Jr.
Director
Telephone Number (505) 667-5101

James M. Williams
General University Activities Contact
Telephone Number (505) 667-3839

The Los Alamos National Laboratory (LANL) is operated for DOE by the University of California under the administrative management of the Albuquerque Operations Office.

The Laboratory's primary mission is the application of science and technology to problems of national security, that is, to the maintenance of a strong defense, the fulfillment of arms control commitments, and the guarantee of a secure energy supply for the future. In carrying out this mission, the laboratory serves as a liaison between research in academia and industry and complements the activities of both. Major programs include developing nuclear warheads, designing and testing advanced technology concepts, and maintaining an innovative weapons design program. In nuclear fission, programs include separating isotopes of uranium by laser induction, testing advanced reactor fuel elements, modeling reactor accident results for the Nuclear Regulatory Commission, evaluating biomedical consequences of nuclear energy production, and developing effective nuclear waste disposal methods. In nuclear fusion, programs include magnetically confined plasma devices (especially high-beta devices), laser-induced fusion, and safe handling techniques for large quantities of tritium. Other programs include nonnuclear energy, basic energy science, and technology utilization.

The Clinton P. Anderson Meson Physics Facility (LAMPF) is located at the Los Alamos National Laboratory and houses an accelerator which is a high current, 800 million electron volt (MeV), proton linear accelerator about one-half mile in length.

LAMPF is considered to be the world's most sophisticated nuclear science facility. It provides unique accelerator-generated beams of protons, pions, muons, neutrons and neutrinos for research programs in basic and applied nuclear science, particle physics, materials science, biomedical investigations, isotope production, and weapons technology.

This is a collaborative research center used by laboratory, university and industry researchers.

Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37831

Herman Postma
Director
Telephone Number (615) 576-2900

George E. Moore
General University Activities Contact
Telephone Number (615) 574-5921

The Oak Ridge National Laboratory (ORNL) is operated for the Department of Energy (DOE) by Martin-Marrietta Energy Systems, Inc., under the administrative management of the Oak Ridge Operations Office.

The Oak Ridge National Laboratory primarily supports fission nuclear fuel cycle and magnetic fusion energy development through scientific research and technology; identifies and solves generic research problems in energy technologies such as materials, separation techniques, chemical processes and biotechnology; and is the major national source of production of stable and radioactive isotopes. Energy technology development at ORNL includes important efforts in residential and commercial energy conservation, renewable energy sources, and coal conversion and utilization.

ORNL has a close working relationship with the Oak Ridge Associated Universities (ORAU) and is a primary recipient of appointments under the ORAU University/Laboratory Cooperative Program. ORNL has a special arrangement with several small college consortia for honors-level, undergraduate student research appointments.

ORNL interacts widely with the academic community through User Facilities. Major facilities and equipment are made available to outside researchers to carry out cooperative and independent projects. Among these are the Holifield Heavy Ion Facility, which houses the accelerators and instruments that are dedicated to heavy-ion studies; the National Environmental Research Park; and many other accelerators, reactors, metallurgical and solid state physics, and biological facilities. In this manner, the Laboratory provides universities with ready access to state-of-the-art research capabilities, training facilities for faculty and students, and an opportunity for collaborative research in areas where these resources are not available to universities.

Pacific Northwest Laboratory
Post Office Box 999
Richland, Washington 99532

Douglas E. Olesen
Director
Telephone Number (509) 375-2201

Sam Farmer
General University Activities Contact
Telephone Number (509) 375-2559

The Pacific Northwest Laboratory (PNL) is operated for DOE by Battelle Memorial Institute under the administrative management of the Richland Operations Office.

The mission of the PNL is the advancement and use of multidisciplinary scientific and engineering technology for national security and the nation's energy needs. In accomplishing this mission, high priority is given to safe and reliable nuclear energy, and to promising new concepts and technologies for operations at the Hanford site. Areas of disciplinary strengths and concentration include nuclear waste process development, nuclear fuel development and evaluation, spent fuel storage and reprocessing, inhalation toxicology, bioelectromagnetics, biology, ecology, atmospheric sciences, corrosion

chemistry, biomass research, nondestructive testing and evaluation, materials characterization and research, chemical engineering, health physics technology, and energy economics and policy analyses.

The laboratory provides a core capability for effectively utilizing the strengths of the universities and the private sector and has traditionally developed and maintained strong ties with the academic community. That resource is utilized through cooperative exploratory research efforts to accelerate application of new ideas, scientific research support to PNL efforts on team assignments, and exchange of staff and student research.

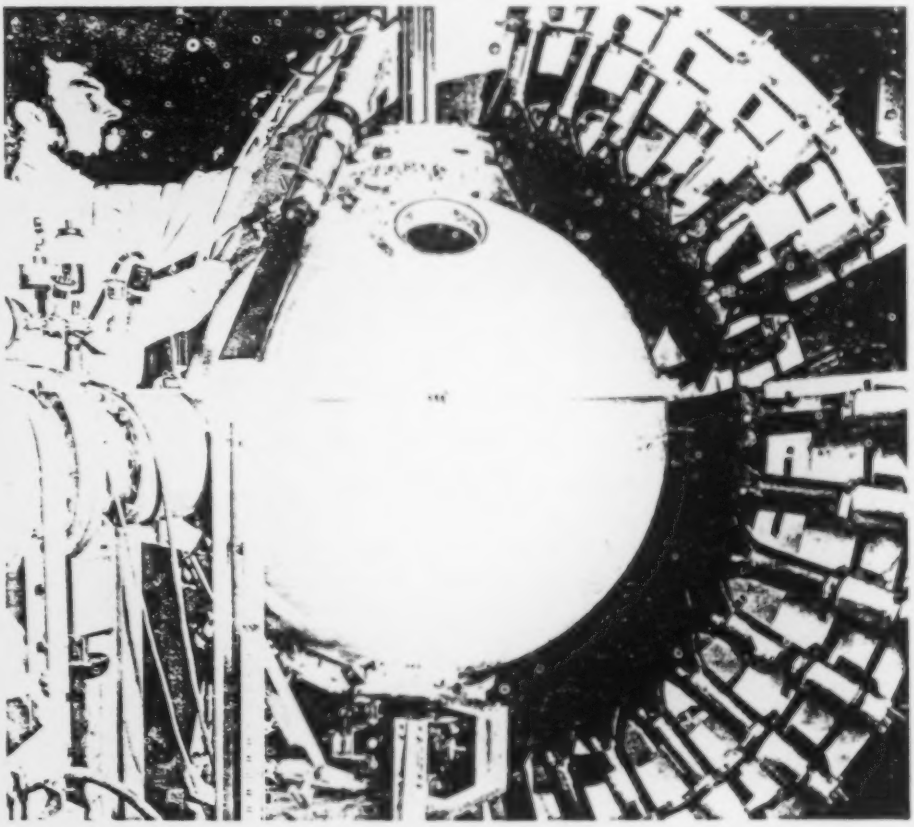
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185

George C. Dacey
Director
Telephone Number (505) 844-7261

James E. Schirber
General University Activities Contact
Telephone Number (505) 844-8134

The Sandia National Laboratories are operated for DOE by the Western Electric Company under the administrative management of the Albuquerque Operations Office.

The laboratories' principal mission has been and remains research, development, and engineering of nuclear weapons systems. Sandia is also responsible for energy programs in fossil, solar, fission, and basic energy sciences. Fundamental understanding and technological development are melded to create an environment conducive to generating new products and processes that are unlikely to be produced in either university or industrial laboratories. These new technologies are transmitted to the private sector through journals, workshops and other information-transfer mechanisms. Sandia Laboratories, Livermore, California, site includes the Combustion Research Facility, a major user-oriented center for fundamental research on combustion phenomena.



DOE Energy Technology Centers

Morgantown Energy Technology Center (METC)
P.O. Box 880
Morgantown, West Virginia 26505

Augustine A. Pitrolo
Director
Telephone Number (304) 599-4511

The Morgantown Energy Technology Center (METC) has responsibility for Unconventional Gas Recovery, Fluidized-Bed Combustion, Gas Stream Cleanup, Fuel Cells, Heat Engines, Surface Coal Gasification, and Component Development for Coal Conversion and Utilization Processes. These activities include the technology development for slurried fixed bed gasifiers, and fluidized-bed combustors as well as characterization, resource inventory, and field tests of unconventional natural gas reservoirs. METC is also responsible for Project Offices at Grand Forks, North Dakota, and Laramie, Wyoming.

In Control Technology, activities include the development of technologies for gas stream cleanup and for waste management and utilization. The primary objective of the gas stream cleanup project is to develop the required technology base for applications in post combustion/utilization devices used as advanced power conversion systems such as fuel cell and gas turbine combined cycles, and, in other conversion processes where significant process improvement results. The purpose of program activities in the fluidized-bed combustion area is to increase the utilization of coal by developing technologies for the pressurized fluidized-bed (PFB) process. The program is designed to provide the technology base necessary to evaluate the potential of both the air and steam combined cycle concepts. METC manages the activities in the Fuel Cells program, developing high-risk, high-payoff technology for cell and stack components. In the Heat Engines program, METC is conducting research and technology development directed toward the solution of major engineering design, durability and performance problems. In the Surface Coal Gasification program, METC is managing in-house and contract research and development involving advances in the state-of-the-art of coal gasification through new concepts development, generation of a technology data base for use by the private sector, and development of technologies for the refinement of existing gasification systems. METC's mission in Unconventional Gas Recovery involves the development of technologies for the recovery of gas from unconventional sources such as eastern Devonian oil shales, western gas sands, methane from coalbeds, methane hydrates and abiogenic gas.

Pittsburgh Energy Technology Center (PETC)
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

Sun W. Chun
Director
Telephone Number (412) 675-6122

Fred W. Steffgen
General University Activities Contact
Telephone Number (412) 675-6133

The Pittsburgh Energy Technology Center (PETC) has responsibilities in the program areas of Direct Utilization, Coal Liquefaction, Coal Preparation, Coal-Water Mixtures, and Flue Gas Cleanup. This includes numerous research and development activities for the industrial use of coal and its derived synthetic fuels in an environmentally sound manner. PETC is also responsible for the handling of *all* unsolicited research proposals pertaining to any part of the Fossil Energy Program.

The PETC program objective in the area of advanced research on direct coal utilization is to establish the technology base and to develop the advanced fossil fuel combustion systems to accelerate the direct utilization of coal in industry and commercial power generation.

The goal of the Coal Liquefaction program is to establish a data base that will facilitate the private sector's development of coal conversion processes for economical production of environmentally acceptable synthetic liquid fuels through generic R&D in high-risk, long-term concepts that have potential for high payoff. The overall strategy will be to support a number of liquefaction concepts in parallel at the laboratory scale. Specific areas of concentration include: (1) the development of new and improved indirect liquefaction technology; (2) the development of more advanced direct coal liquefaction processes for further private sector development and demonstration; and, (3) the generation of supporting data in the areas of environmental and health effects, key instrumentation and components, engineering analyses and data base management.

The effort in the University Coal Research program is aimed at establishing research grants at colleges and universities for basic and applied research to improve scientific and technical understanding of the fundamental processes involved in the conversion and utilization of coal.

The Coal Preparation program focuses on the development of advanced coal cleaning technologies required by private industry to meet the anticipated growth in the demand for higher quality coal. Parallel efforts under Alternative Fuel Mixtures within the Combustion Systems activity are directed towards the preparation and utilization of highly cleaned coal water slurries as retrofit fuels for oil and gas designed units.

The flue gas cleanup program focuses on the development of a technology base for simple, cost effective and environmentally superior processes that remove pollutants from coal combustion gas streams in both utility and industrial boilers in light of existing, as well as anticipated, more stringent environmental standards.

DOE Sponsored Consortia

Associated Western Universities
142 East 200 South, Suite 200
Salt Lake City, Utah 84111

Donald Walker
Director
Telephone Number (801) 364-5656

Madeleine Franco
General University Activities Contact
Telephone Number (801) 364-5656

The Associated Western Universities is an outgrowth of the Associated Rocky Mountain Universities (ARMU) organized in Colorado in 1959 by several of the major universities in the Rocky Mountain Region. In 1964, the organization entered into a contract with the U.S. Atomic Energy Commission (AEC) to assist with the training of students and faculty members in the sciences and engineering associated with the nuclear industry through working with the AEC's contractor laboratories in the western United States. This relationship has continued with the Department of Energy. AWU does not carry out research but does encourage new research ideas among faculty of the universities by acting as a clearinghouse for ideas and by stimulating cooperation among the faculty and students of the universities and scientists at DOE and other laboratories.

As one participant in the DOE University-Laboratory Cooperative Program (administered by the Office of Energy Research Division of University and Industry Programs) AWU supports faculty and student participation in energy-related research projects at AWU cooperative laboratories and facilities throughout the Western United States. These facilities include such laboratories as the Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Lawrence Berkeley Laboratory, Laboratory for Energy-Related Health Research, Laboratory of Biomedical and Environmental Sciences, Inhalation Toxicology Research Institute, Jet Propulsion Laboratory, Sandia National Laboratories and many, others. AWU coordinates activities for the Lab/Coop program including: undergraduate research study; graduate thesis and non-thesis research; and faculty and/or post-graduate research appointments.

AWU has cooperative arrangements with twenty-six major facilities in the western United States. Research disciplines include the physical sciences—biology, chemistry, geology, mathematics and computer science, and physics—and several of the engineering fields such as chemical, electrical, mechanical, metallurgical, nuclear and petroleum engineering. Application forms for AWU programs may be obtained from the address indicated above.

Northwest College and University Association for Science
Joint Center for Graduate Study
100 Sprout Road
Richland, Washington 99352

Bryan Valett
Director
Telephone Number (509) 375-3176

The Northwest College and University Association for Science (NORCUS) is an association of fifty-two schools in the five northwest states: Alaska, Idaho, Montana, Oregon and Washington. Members include institutions at all levels—from four-year graduate universities to two-year community colleges. Located at the Joint Center for Graduate Studies, NORCUS conducts appointment programs in science and engineering. The Association is supported through grants with the University of Washington acting as the administrative contractor and interfaces with the six DOE contractor laboratories in the Richland area.

NORCUS programs include: undergraduate research participation; graduate student research; and faculty research appointments. Faculty and student appointments may be made in the following fields: chemistry, mathematics, metallurgy, physics, computer science, engineering (nuclear, mathematical, chemical, electrical), biology, radiobiology, environmental science, and alternative energy studies.

Application forms for NORCUS programs may be obtained from the address indicated above.

Oak Ridge Associated Univerities
Post Office Box 117
Oak Ridge, Tennessee 37830

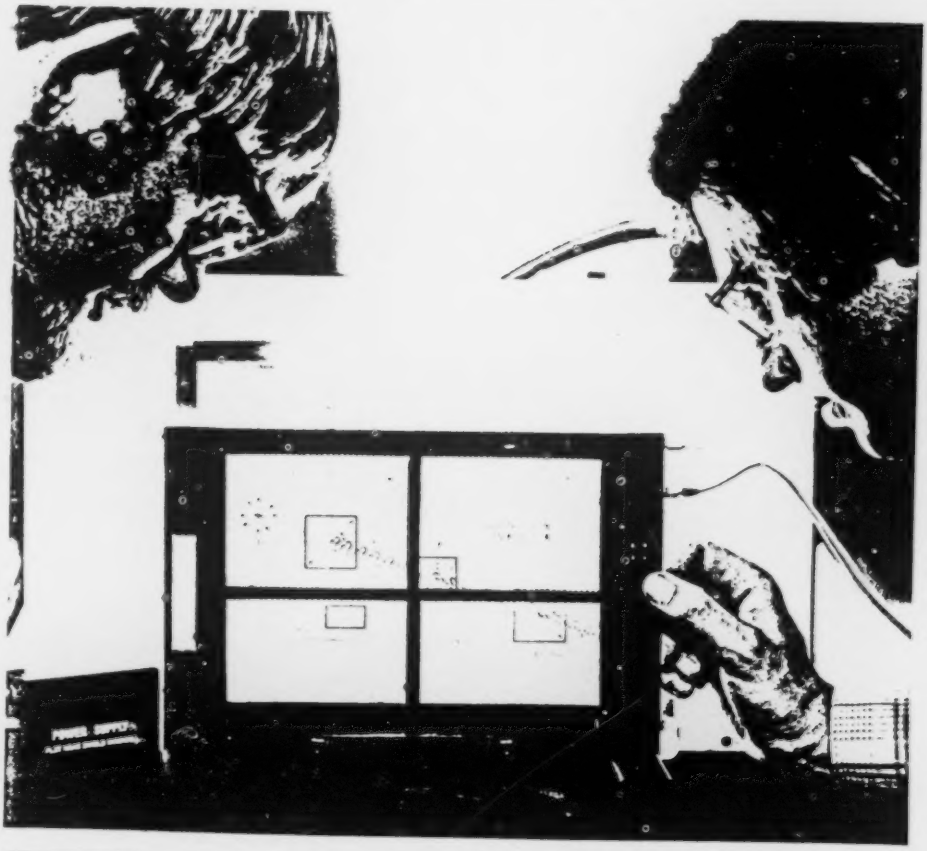
William E. Felling
Executive Director
Telephone Number (615) 576-3300

Al Wohlpart
General University Activities Contact
Telephone Number (615) 576-3421

The Oak Ridge Associated Universities (ORAU) is a private, not-for-profit association of more than 50 colleges and universities mainly in the southeastern U.S. It has been a contractor of the U.S. Department of Energy (and its predecessor agencies) for over 35 years conducting research and educational programs in the areas of energy, health and the environment.

Within the University Laboratory Cooperative Program research opportunities are provided for faculty, graduate students and undergraduate students in both summer and academic year programs at seven DOE facilities (including the Oak Ridge Associated Universities; the Oak Ridge National Laboratory; Savannah River Laboratory; the Savannah River Ecology Laboratory, Center for Energy and Environment Research, Puerto Rico; Atmospheric Turbulence and Diffusion; and the Martin Marrietta Energy Systems, Inc.). These research programs relate to energy production, utilization, conservation and their societal implications. Appointments are available in the life, physical and social sciences, mathematics; and engineering.

Application forms for ORAU programs may be obtained from the address indicated above.



Part IV.
DOE Procurement and Assistance Policies/Procedures

Introduction

The Assistant Secretary for Management and Administration is the business manager of DOE responsible for budget, financial operations procurement, cost estimating and the development of business-related policy.

Of the offices reporting to the Assistant Secretary, the Director of Procurement and Assistance Management, is the principal official and business advisor on all procurement, financial assistance, sales and other business arrangements for DOE. The Director is responsible for establishing overall policy and regulations for the Department in the areas of procurement, financial assistance, sales, and contract management; providing functional management and review of the field buying offices; providing support for advance planning related to procurement and financial assistance programs; and managing the operation of the Source Evaluation Board process. The Director is also responsible for the Headquarters Office of Procurement Operations, which is the largest procurement office in DOE.

Some of the responsibilities and activities of the Procurement and Assistance Management Directorate are discussed on the following pages.

There are two principal means by which a researcher may obtain DOE funding or other support for research projects. Each of these begins with the preparation and submission of a proposal. A proposal submitted in response to a solicitation issued by DOE is termed a "solicited proposal," whereas a proposal prepared and submitted solely on the researcher's own initiative is an "unsolicited proposal."

Information detailing the steps for preparing and submitting a solicited proposal will be found within the text of the solicitation. For unsolicited proposals, researchers who have original, unsolicited ideas that they believe would be of interest to one of the program entities identified in Part I, will find an overview of the steps necessary to obtain DOE support in Part IV.

Sections of Part IV describe generally the DOE solicitation process including solicitation characteristics, proposal requirements, proposal evaluation, types of award instruments, and DOE project management procedures.

It should be noted that the Federal Procurement Regulations (FPR's)* and the DOE Procurement Regulations (DOE/PR's)* generally govern all procurement relationships with DOE, and the DOE Financial Assistance Rules (issued October 5, 1982) govern all financial assistance relationships with the Department. DOE regulations for procurement are found in 41 Code of Federal Regulations (CFR) Chapter 9; for grants and cooperative agreements, they are found in 10 CFR part 600.

Competitive Solicitations

There are several types of competitive solicitation documents issued by DOE. Various types of solicitations that call for the submission of proposals or applications are described below.

- *Program Opportunity Notice (PON)*—A notice used principally to solicit competitive proposals for non-nuclear energy demonstration projects when there is a stated general objective, but no prescribed statement of work, and diverse approaches are desired. PON's may result in the award of procurement contracts or financial assistance instruments.
- *Program Research and Development Announcement (PRDA)*—An announcement used to solicit a broad mix of research, development, and related energy project proposals. While a Program Opportunity Notice is geared strictly to demonstration projects utilizing existing, commercially applicable technology, a PRDA solicits proposals for projects in areas where research and development is required within broadly defined areas of interest, but it is difficult to describe in detail the nature of the work contemplated because of:
  - — The multiplicity of possible approaches available for solving the problems;
  - — The desirability of using several organizations in solving the problems posed;
  - — The expectation that many proposers will have qualifications or specialized capabilities that will enable them to perform portions of the program, so that the support may be broken into segments that cannot be ascertained in advance; and
  - — The desirability of fostering new and creative solutions.

  PRDA's may result in the award of procurement contracts or financial assistance instruments.
- *Solicitation for Financial Assistance Applications*—A program rule or regulation or other publicly available document used to invite the submission of applications for grants and/or cooperative agreements by a common due date or within a prescribed period of time. The solicitation or a notice of the availability of the solicitation will be published in the *Federal Register* and, as appropriate, in the *Commerce Business Daily*.

Synopses of these competitive solicitation notices are published in the *Commerce Business Daily* and may also

*Effective April 1984, the Federal Procurement Regulations (FPR's) and the DOE Procurement Regulations (DOE/PR's) were replaced by the Federal Acquisition Regulation (FAR) and the Department of Energy Acquisition Regulation (DEAR).

be published in professional journals and news publications. Such publication is in keeping with the DOE policy of providing timely notice to the public as to the availability of assistance awards and acquisition contracts.

Two other types of solicitation documents are used to solicit competitive proposals for procurement contracts in accordance with the Federal Procurement Regulations:

- *Invitation for Bids (IFB)*—A document used to solicit bids in response to detailed specifications. Award is based on price competition, and a fixed price type of procurement contract usually results. Requirements are usually of a hardware nature and formal advertising procedures are followed. They contain detailed specifications, terms and conditions of the procurement. Each invitation for bid also sets forth the place, date and time for the formal opening and recording of bids. The evaluation and award process is conducted in strict compliance with the Invitation for Bids and in accordance with procurement regulations.
- *Request for Proposal (RFP)*—A document used to solicit proposals in response to a broader statement of work that normally incorporates performance specifications rather than detailed design specifications. Each Request for Proposal sets forth the place, date and time for the submission of proposals. The evaluation, selection, negotiation and award process is conducted in accordance with the terms of the solicitation document and procurement regulations.

Universities responding to competitive announcements will be expected to comply with all conditions stated in the announcements for proposal submission, review and evaluation. If an award results, they will similarly be expected to meet all stipulated requirements for reporting, audits and the like.

Unsolicited Proposals

Policies

Because present and future energy needs demand full exploitation of all energy alternatives, it is DOE policy to encourage individuals and organizations to submit unsolicited proposals on unique, innovative approaches and ideas that they believe merit public support.

In furtherance of this policy, DOE will:

- Publicize DOE interest in unsolved technical issues whose solutions are considered relevant to the accomplishment of DOE's mission;
- Process unsolicited proposals in an expeditious manner and keep proposers advised as evaluation and acceptance decisions are made;
- Ensure that all possible sponsors within the Department are aware of the proposal's existence;
- Ensure that each proposal is evaluated in a fair and objective manner;
- Ensure that each proposal is used only for its intended purpose (all Government and Non-Government personnel handling unsolicited proposals shall exercise extreme care to ensure that the information contained therein is not duplicated, used or disclosed in whole or in part for any purpose other than to evaluate the proposal, without written permission of the offeror);
- Encourage the submitter of an unsolicited proposal to mark it "Proprietary Data" with a legend restricting the disclosure and use of the data as marked in the proposal. If a proposal contains proprietary data, it may be marked with notice in accordance with the procedure in the DOE-PR, 9-3.150-2(a) or 10 CFR 600.18. (The disclosure of such information concerning trade secrets, processes, operations, style of work, apparatus, and other matters, except as authorized by law, may result in criminal penalties);
- Encourage program staffs to develop and publish statements of program interest in those technical areas and new technology directions that might be addressed by unsolicited proposals from the research community; and
- Obtain signed non-disclosure statements from reviewers outside of the Government when external review is deemed necessary and appropriate. (The non-disclosure statement ensures that the reviewer will use the information contained in the proposal for evaluation purposes only.)

Procedures

An unsolicited proposal is submitted solely on the initiative of the proposer. The idea presented in a proposal may be prompted by a Notice of Program Interest; however, this is not a prerequisite for the submission of an unsolicited proposal. A Notice of Program Interest may be published by DOE whenever the Department wishes to stimulate a particular program effort but has not specifically identified any projects. Notices provide information about DOE interest in innovative approaches applicable to specific problem areas involving energy and related technology utilization. They are *not* formal solicitations, but are instead a communication device that informs and helps potential proposers focus on areas where unsolicited proposals may be mutually beneficial to DOE programs and the proposer. They are generally published

in the *Commerce Business Daily* or the *Federal Register*, and widely distributed to industry associations, including small business associations; schools, colleges and universities; appropriate professional and scientific journals; state, local and regional governmental organizations; other DOE offices; and individuals and organizations who request copies on a one-time basis.

In the unsolicited proposal, the proposer must present project objectives and their pertinence to the DOE mission; justify the rationale of the approach and the methods to be employed; indicate the relevant qualifications of the investigator(s) and sponsoring institution, and the level of funding required to attain the objectives. The proposal should be self-explanatory and written with clarity and thoroughness. It alone will serve as the means to persuade the staff of DOE, and other qualified members of the scientific and engineering community who might review it for DOE, that the proposed project is worthwhile.

The Department of Energy is not responsible for costs incurred in the preparation of either solicited or unsolicited proposals. Prior to expending resources in the development of an unsolicited proposal, prospective proposers are encouraged to consult informally with DOE program personnel by letter, telephone, or personal visit to ascertain their potential interest. Such preliminary contact serves to establish an understanding between the proposer and DOE, and should reduce paperwork and loss of time. Note that these informal discussions do not constitute authorization to perform work at Government expense in anticipation of an award. The names of DOE staff members consulted should be included in the transmittal letter that accompanies the unsolicited proposal, to ensure their receipt of the proposal.

The unsolicited proposal forms the basis for both further technical evaluation and contract negotiations. Although no particular format need be followed for the submission of unsolicited proposals, there are several items that must be included. These are basic information about the submitter, his or her organization and proposed project dates; project business and financial information including cost and labor hour requirements; and project technical information including a detailed statement of work with sufficient technical detail to permit a meaningful evaluation, and facility and equipment requirements, if any.

General policy and procedures concerning the receipt, evaluation and acceptance of unsolicited proposals are set forth in Federal Procurement Regulations 1-4.9, DOE Procurement Regulations 9-4.9 and DOE Assistance Regulation 600.14. It should be noted that the Department encourages the submission of multiyear proposals where the research can be reasonably expected to continue over several years.

Further information on the submission of unsolicited proposals can be found in the DOE booklet entitled "Guide for the Submission of Unsolicited Proposals" (DOE/MA-0095). The material in the booklet, along with information learned through informal consultation, will assist the proposer in producing an unsolicited proposal that contains sufficient information to permit evaluation. This booklet is available from the office listed below.

There are no specific dates for the submission of unsolicited proposals; but, because a comprehensive review is required before a proposal can be acted upon, new proposals should be submitted as early as possible, usually a minimum of six months in advance of the desired period of support. However, it should not be assumed that in all cases a six-month lead time is adequate. Proposals should be submitted to:

Unsolicited Proposal Coordinator
Reports and Analysis Branch
Procurement and Assistance Management Directorate
U.S. Department of Energy
Washington, D.C. 20585

The Unsolicited Proposal Coordinator is responsible for logging and monitoring the status of all unsolicited proposals formally submitted to DOE. If the proposer has identified the appropriate program office to which a specific proposal is to be reviewed, the unsolicited proposal may be sent to that office with a letter of transmittal. That office is then responsible for advising the Unsolicited Proposal Coordinator of its receipt for control purposes. The Coordinator will acknowledge receipt of the unsolicited proposal, provide the DOE control number and identify the program office(s) to which the proposal has been referred. Some proposals may have the potential for support by more than one DOE program office, in which case the proposal may be referred to all potentially interested groups.

It should be noted that the Office of Minority Economic Impact, pursuant to Section 211(e)(1) of Public Law 95-619 and 10 CFR Part 800, has authority to issue loans to minority business enterprises to assist them by financing up to 75 percent of the costs incurred in preparing bids or proposals seeking DOE contracts or assistance. Information regarding loan availability, eligibility criteria, and application procedures may be obtained from:

San Francisco Operations Office, USDOE
1333 Broadway
Oakland, California 94612
Attn: Grants and Loan Division
Phone: (415) 273-4461

Proposal Review and Evaluation

Solicited Proposals

Solicitations set forth the specific criteria to be used in the proposal evaluation and review process. Such proposals are normally reviewed only by Government personnel.

Unsolicited Proposals

A. Review

Prior to making a comprehensive evaluation, DOE will review the proposal to determine whether the document contains the minimum prescribed information, has been approved by a person authorized to represent the proposer organization and falls within the scope of an unsolicited proposal. If the proposal satisfies the requirements of the preliminary review, copies will be forwarded to appropriate offices for evaluation.

If the document does not satisfy all of the foregoing requirements, it will be treated as a preliminary proposal. If the decision made as a result of this preliminary review is unfavorable, no further comprehensive evaluation may

be made. The proposer will be told how the document has been interpreted and the reason it is not being considered as an unsolicited proposal. However, if the document contains most of the information required and appears to have technical merit, the missing information may be requested so that it can be processed as an unsolicited proposal.

B. Evaluation

The detailed evaluation criteria used in reviewing an unsolicited proposal are contingent upon whether the project, for which the proposal is to be considered, is principally one of acquisition or assistance.

- If the project is principally one of assistance, the supporting instrument will be an assistance instrument, i.e., either a grant or cooperative agreement. The evaluation criteria for assistance instruments are set forth in the DOE Assistance Regulations. (See 10 CFR part 600)
- If the project is principally one of acquisition, the supporting instrument will be a contract. The evaluation criteria for contracts are set forth in the Federal and DOE Procurement Regulations. (See FPR 1-4.9 or DOE/PR 9-4.9)

For the past three years, approximately 22 percent of the unsolicited proposals reviewed by DOE were funded. If DOE decides to support a proposal, the proposer will be so advised but may be asked to submit additional details, to revise budgets, or to confirm the proposal goals as approved. Plans for initiating the project may be agreed upon at that time. However, no actual commitment of funds may be made by the recipient until formal notification action is completed. Preaward costs are generally not allowable. When the program office has determined that a proposal will be funded, contract office personnel will be requested to negotiate the award instrument with the firm concerned. Cognizant DOE offices have been designated for most major colleges and universities.

An unsolicited proposal may propose activities that are also of interest to other Federal agencies. In such cases, with the prior written approval of the proposer, interagency proposal evaluation may be initiated. If the proposal is found acceptable, another agency may fund the unsolicited proposal or DOE may jointly fund the program with the other agency.

Types of Award Instruments

Projects usually fall into one of two classes, acquisition or assistance. The determination of whether a project is one of acquisition or assistance is made at a DOE program policy level.

There are three types of instruments generally used by DOE to provide funds for research projects: grants, cooperative agreements, and procurement for contracts (including Special Research Contracts). The choice of award instrument lies within the administrative discretion of DOE, except when prohibited or limited by law. The decision as to which form of award instrument will be used is based on the purpose of the project and the extent of Federal involvement necessary to ensure project success. An award instrument identifies the terms and conditions, and the nature of this relationship between DOE and the recipient.

- A procurement contract is used as the funding instrument whenever the principal purpose is the acquisition by purchase, lease, or barter of property or services for the direct benefit or use of the Federal Government, or whenever DOE determines in a specific instance that the use of a contract is appropriate.
  - —A Special Research Contract (SRC) is a simplified form of procurement contract which may be used for educational and not-for-profit research institutions conducting basic research, where the annual DOE support does not exceed $1,000,000.
- An assistance instrument is used to provide support whenever the principal purpose is to accomplish a public purpose of support or stimulation authorized by Federal statute.
  - —A "grant" is used whenever no substantial involvement is anticipated between DOE and the recipient during performance of the activity.
  - —A "cooperative agreement" is used whenever substantial involvement is anticipated between DOE and the recipient during performance of the activity. Each cooperative agreement shall include an explicit statement of the nature, character and extent of the anticipated DOE involvement.

Patent, Data and Copyrights

Under DOE statutory patent policy, DOE normally reserves the right to title in all inventions conceived or first actually reduced to practice in the course of or under contracts, grants, or other agreements involving research, development or demonstration. In such instances, the contractor or assistance recipient is normally reserved a royalty-free, nonexclusive, revocable license for the use of such inventions. However, at or before award, a contractor or recipient is permitted to request an advance waiver of the Government's rights in inventions. Also, the contractor or recipient may request waiver of the Government's rights in identified inventions after the time of contracting.

The recent passage of Public Law 96-517 now permits small business firms, universities and other educational institutions and non-profit organizations to retain title to inventions if they elect to do so. Only under exceptional circumstances will the Government retain title to an invention discovered or reduced to practice under a funding arrangement with these types of organizations. The Government is provided with a royalty free license, however.

DOE recognizes that a contractor, assistance recipient or their employees may desire to publish, within the limits of security requirements, information regarding scientific or technical developments made or conceived in the course of their work under agreement with DOE. So that premature public disclosure of such information will not adversely affect the patent interest of DOE, the contractor, or the assistance recipient, the contract or grant provides DOE with a 60-day period to determine whether patent protection should be obtained prior to release of information.

DOE Procurement Regulations, and DOE Assistance Regulations contain policies and detailed procedures on patents, data and copyrights.

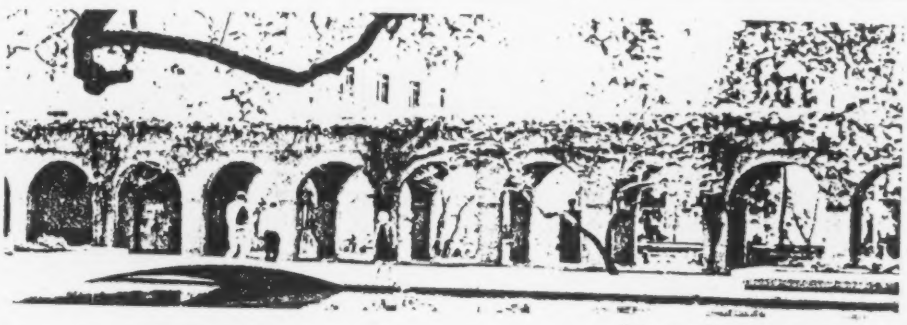


Photo courtesy of the California Institute of Technology

Classification Research and Security Considerations

Classification

Most proposals for DOE research and development projects are unclassified. If, however, during the evaluation of a proposal it is found that the work will be in or border on a classified topic, any resulting contractual arrangement will take this into account and the assistance recipient or contractor will be required to comply with applicable Government security regulations. Certain contractual provisions or assistance conditions can be included in an award instrument to allow for termination of the arrangement, should a classified topic develop during the course of work.

Security

Where possible, an unclassified proposal should be submitted. However, if this is not feasible, the proposal must be classified in accordance with its content. Additional guidance with regard to the preparation, handling and disposition of a classified proposal may be obtained from:

Director of Security
U.S. Department of Energy
Washington, D.C. 20585

Reports

Recipients of financial assistance or procurement contract awards will be expected to satisfy reporting requirements stipulated in the solicitation, the award instrument, or applicable regulations. For additional information on procurement contract reporting, see the applicable DOE Orders.*

The selection of appropriate reports, their frequency and the amount of detail will vary with several factors including the program objectives, amount of funding and type of instrument awarded. DOE program managers have been instructed to use discretion in report selection in order to keep administrative burdens to a minimum.

Audits

Office of Management and Budget Directives require contracts, grants and cooperative agreements to include a requirement to examine periodically the books and records of the recipients of a contract or financial assistance award.

Audit functions of the Department are the responsibility of the DOE Inspector General and are performed in accordance with generally accepted auditing standards and applicable Federal regulations. However, the cognizant audit agency for most colleges and universities is the U.S. Department of Health and Human Services. In certain instances, DOE itself may conduct an audit of awards to a university. Audits of commercial organizations are generally conducted by the Defense Contract Audit Agency (DCAA).

The objectives of audits are to determine whether a contractor's or assistance recipient's management, accounting, procurement, and property control systems and procedures provide assurance to DOE that costs claimed are reasonable, allowable and allocable under the procurement and assistance terms and conditions; and to review for compliance with applicable Federal and DOE procurement and assistance regulations, and provide recommendations for improvement where needed.

Audit questions should be directed to the Office of Policy, Business and Financial Policy Branch, Procurement and Assistance Management or the Office of the Inspector General, U.S. Department of Energy, Washington, D.C. 20585.

---

*DOE Order 1332.1, Uniform Reporting Systems Contractors, October 31, 1983, and
*DOE Order 1332.2, Uniform Reporting System for Federal Assistance (Grants and Cooperative Agreements), October 31, 1983

May be obtained from:

U.S. Department of Energy
Office of Project & Facilities Management, MA-22
1000 Independence Avenue, S.W., Room 5C-032
Washington, D.C. 20585

Glossary

B/O (Budget Outlays) — The sum of the outlays (disbursements from appropriations and funds, less offsetting receipts.

Cooperative Agreements and Grants — Award instruments between the DOE and state government, university, or other recipient whereby the DOE provides assistance in the form of money, property, services or anything of value to the recipient to accomplish a public purpose of support or stimulation. A cooperative agreement is similar to a grant except that it describes a relationship whereby the Government has substantial involvement with the recipient during the performance of the effort. A grant calls for comparatively little Government involvement.

Financial Assistance — Government-provided funds or aid in kind to accomplish a public purpose of stimulation or support authorized by Federal statute. It includes cooperative agreements and grants.

Notice of Program Interest — A published statement of DOE program interest in general technical problem areas needing investigation which might be addressed by unsolicited proposals.

Procurement Contract — A contractual instrument used when the Federal Government procures property or services for its direct benefit, i.e., use or consumption.

Program — An organizational set of activities directed toward a common purpose, objective, or goal undertaken or proposed by an agency in order to carry out responsibilities assigned to it.

Project — An endeavor with a specific objective to be met within prescribed time and dollar limitations and which has been assigned for work definition or execution.

Solicited Proposal or Application — A written response to a formal solicitation notice issued by the Government, generally in a competitive acquisition or assistance process.

Unsolicited Proposal — A written offer to perform a proposed effort submitted solely on the initiative of the offerer, with the objective of obtaining financial support and not in response to a specific request of the Government.

References and Bibliography

1. Guide for the Submission of Unsolicited Proposals (DOE/MA-0095), June 1983, GPO, NTIS.
2. Commerce Business Daily, available by subscription from GPO.
3. Federal Register, available by subscription from GPO.
4. Catalog of Federal Domestic Assistance, available by single copy or subscription from GPO.
5. OMB Circular Nos. A-21, A-102, A-110 and A-111, OMB.
6. Department of Energy Acquisition Regulation (DEAR) 48 CFR Chapter 9, GPO.
7. Federal Register, DOE Assistance Rules, (10 CFR Part 600), October 5, 1982, GPO.
8. Standards for Audit of Governmental Organizations, Programs, Activities and Functions, issued by the Comptroller General of the United States, GPO (Stock Number 020-000-00110-1).
9. DOE Research and Development and Field Facilities (DOE/ER-0029), June 1979, GPO (Stock Number 061-000-00318-5), NTIS.
10. Headquarters DOE Telephone Directory (DOE/MA-0024/16), GPO/NTIS.
11. DOE Order 1332.1, Uniform Reporting System for Contractors, October 31, 1983, DOE.
12. DOE Order 1332.2 Uniform Reporting System for Federal Assistance (Grants and Cooperative Agreements), October 31, 1983, DOE.

Publications listed above can be obtained from:

GPO — Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
(202) 783-3238

NTIS — National Technical Information Service
Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

OMB — Office of Management and Budget
Publication Office
Office of Administration
726 Jackson Place, N.W.
Room G-236
Washington, D.C. 20503

DOE — U.S. Department of Energy
Office of Project & Facilities Management, MA-22
1000 Independence Avenue, S.W.
Room 5C-032
Washington, D.C. 20585

Appendix

Summary of DOE Research and Development Activities[1]

PROGRAMS	FY 1983 BUDGET AUTH. (ACTUAL) ($ IN MILLIONS)		FY 1984 BUDGET AUTH. (ESTIMATE) ($ IN MILLIONS)		FY1985 BUDGET AUTH. (PRESIDENTIAL REQ.)[2] ($ IN MILLIONS)	
	TOTAL R&D	UNIVERSITY R&D SUPPORT	TOTAL R&D	UNIVERSITY R&D SUPPORT	TOTAL R&D	UNIVERSITY R&D SUPPORT
OFFICE OF ENERGY RESEARCH						
UNIVERSITY RESEARCH SUPPORT	6.0	2.2	9.5	6.3	15.2	10.1
BASIC ENERGY SCIENCES	267.2	68.2	291.9	73.1	344.5	86.3
HEALTH & ENVIRONMENTAL RESEARCH	170.2	45.3	165.9	40.6	174.6	39.7
HIGH ENERGY PHYSICS	325.3	57.7	342.5	62.6	342.5	70.0
MAGNETIC FUSION ENERGY	361.1	45.2	402.4	44.5	413.0	45.3
NUCLEAR PHYSICS	116.1	28.7	131.0	34.3	134.0	38.3
PROGRAM ANALYSIS	2.6	.2	2.8	.3	2.9	.2
TOTAL:	1248.5	247.5	1346.0	261.7	1423.8	288.9
OFFICE OF CONSERVATION & RENEWABLE ENERGY						
Conservation Programs						
BUILDING ENERGY R&D	35.1	1.9	36.0	1.9	35.3	1.2
ENERGY CONVERSION & UTILIZATION TECH.	9.0	.0	9.0	.0	21.3	.0
ELECTRIC ENERGY SYSTEMS	17.2	2.1	18.5	1.0	18.2	3.0
ENERGY FROM MUNICIPAL WASTE	3.0	.3	1.5	.5	3.0	1.3
ENERGY STORAGE SYSTEMS	25.7	2.0	25.7	2.0	17.1	1.2
INDUSTRIAL PROGRAMS	10.7	4.0	33.7	.5	33.3	.3
VEHICLE AND ENGINE R&D	65.6	.7	65.0	.4	51.1	.2
SUBTOTAL:	167.3	11.0	189.4	6.3	179.3	7.2
Renewable Energy Programs						
ACTIVE HEATING & COOLING	6.7	1.0	17.2	.8	11.9[3]	.1[3]
BIOMASS ENERGY TECHNOLOGY	17.3	1.6	29.0	.8	28.1	.1
GEOTHERMAL & HYDROELECTRIC ENERGY TECH.	59.6	3.5	30.2	1.5	27.5	2.0
OCEAN ENERGY TECHNOLOGY	10.5	.3	7.0	.0	3.5	.0
PASSIVE & HYBRID SOLAR	11.3	.4	0	.0	.0[3]	.0[3]
PHOTOVOLTAIC ENERGY TECHNOLOGY	32.7	10.5	51.2	4.9	47.5	.4
SOLAR THERMAL ENERGY TECHNOLOGY	22.0	1.3	41.5	.8	37.5	.1
WIND ENERGY	42.6	1.8	22.8	1.0	23.3	.1
SUBTOTAL:	202.7	20.4	198.9	9.8	179.3	2.8
TOTAL:	370.0	31.4	388.3	16.1	358.6	10.0
OFFICE OF DEFENSE PROGRAMS						
DEFENSE WASTE & BYPRODUCTS MANAGEMENT	226.0	3.7	309.0	3.8	116.2	3.8
INERTIAL FUSION	140.0	11.9	145.0	10.9	125.0	6.7
MILITARY APPLICATION	1051.1	1.3	1192.6	1.4	1151.2	2.2
NUCLEAR MATERIALS PRODUCTION	117.9	.5	116.4	.5	121.0	.5
SAFEGUARDS AND SECURITY	36.1	.0	40.5	.0	48.8	.0
TOTAL:	1571.1	17.4	1803.5	16.6	1562.2	13.2

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DOE/S-0025
Vol. I of II

An Assessment of the Relationships Between The Department of Energy and Universities and Colleges

Volume I

Prepared by
The University Programs Panel
August 1983

A Report of the
Energy Research Advisory Board
to the
United States Department of Energy
Washington, D.C. 20585

Energy Research Advisory Board
to the
United States Department of Energy
1000 Independence Avenue, S.W.
Washington D.C. 20585
(202) 252-8933

Honorable Donald Paul Hodel
Secretary of Energy
Washington, D.C. 20585

Dear Mr. Secretary:

I am pleased to forward the final Report prepared by the University Programs Panel of the Energy Research Advisory Board (ERAB). This report, discussed and approved unanimously by the ERAB on August 4, 1983, was prepared in response to the request by former Deputy Secretary W. Kenneth Davis on November 5, 1982, to examine the interrelationships between the Department of Energy and the Nation's colleges and universities. The Board was also requested to evaluate the effectiveness of the Department's policies and programs with the academic community.

The Department and its predecessor agencies have had long-standing relationships and programs with universities, both directly in terms of on-campus research projects and indirectly through the programs and resources of the National Laboratories. The University Programs Panel looked in depth at university participation in Departmental programs. There is no question that the Department has had a major and positive impact on many areas of university research and education, particularly in the nuclear and physical sciences. However, the Panel also noted a number of issues and concerns that have developed over time and have unduly affected and limited the participation of university researchers in Departmental programs. These issues are dealt with at length in the Panel's report and a number of recommendations are proposed to reduce or eliminate the reasons behind them.

Among the principal findings and recommendations in this report is the need for the Department, at the level of the Secretary, to articulate clearly its view of the proper university role in support of Departmental programs. Related to this is the need for the Department to establish an agency-wide R&D program planning process which provides opportunities for university and other scientists to contribute to the development of future research agendas and priorities for each major Departmental program. The Panel recommends that the Department should explicitly recognize its obligation to play a significant supporting role in the overall national effort to ensure adequate numbers of highly skilled scientists and engineers. Finally, the Panel recommends that the exchange of information between university scientists and administrators and Departmental program and policy staff needs to be significantly improved and expanded.

The Board agrees that the Nation's universities are an essential resource for the Department both in terms of the development of new scientific and technical concepts and in the preparation of the next generation of scientific and technical leadership for future energy R&D programs. The recommendations in this report are designed to suggest to the Department means by which university capabilities can be utilized even more effectively in support of the Department's missions.

Sincerely,

Louis H. Roddis, Jr.
Chairman, Energy Research
Advisory Board

Enclosure

Energy Research Advisory Board
to the
United States Department of Energy
1000 Independence Avenue, S.W.
Washington D.C. 20585
(202) 252-8933

August 1, 1983

Mr. Louis H. Roddis, Jr.
Chairman
Energy Research Advisory Board
U.S. Department of Energy
Washington, D.C. 20585

Dear Louis:

I am pleased to transmit on behalf of the University Programs Panel of the Energy Research Advisory Board its report prepared in response to a request dated November 5, 1982, from former Deputy Secretary W. Kenneth Davis asking the Board to examine the roles and missions in energy research and development undertaken by the universities and the effectiveness of the Department's policies toward and working relationships with the academic community.

The Panel very much appreciates the cooperation of the staff of the Department of Energy and the detailed, helpful information provided by the universities.

Sincerely,

Ivan

Ivan L. Bennett
Chairman
University Programs Panel

ENERGY RESEARCH ADVISORY BOARD

Chairman

Louis H. Roddis, Jr., P.E.
Consulting Engineer
Charleston, S.C.

Vice Chairman

Ivan L. Bennett
Professor of Medicine
New York University Medical Center

MEMBERSHIP

Betsy Ancker-Johnson
Vice President
Environmental Activities Staff
General Motors Technology Center

Frank P. Baranowski
Nuclear Consultant
Great Falls, Va.

Solomon J. Buchsbaum
Executive Vice President
Customer Systems
Bell Laboratories

Melvin Calvin
Professor of Chemistry
Department of Chemistry
University of California

William D. Carey
Executive Officer
American Association for the
Advancement of Science

Charles F. Cook
Vice President for R&D
Phillips Petroleum Company

Floyd L. Culler, Jr.
President
Electric Power Research Institute

Gerald L. Decker
President & Chief Executive Officer
Decker Energy International, Inc.

John S. Foster, Jr.
Vice President for Science
and Technology
TRW, Inc.

Charles J. Hitch
President Emeritus
University of California

Henry R. Linden
President
Gas Research Institute

William T. McCormick, Jr.
President
American Natural Resources Co.

Laurence I. Moss
Environmental Consultant
Estes Park, Colo.

David Pimentel
Professor
College of Agriculture
Cornell University

Robert H. Pry
Vice Chairman—Technology
Gould, Inc.

Eric Reichl
President (Retired)
Conoco Coal Development Co.

Alan Schriesheim
General Manager
Engineering Technology Department
Exxon Research and Engineering Co.

John W. Simpson
Consultant to International
Energy Associates, Ltd.
Hilton Head, S.C.

Clifford V. Smith, Jr.
Special Assistant to the Chancellor
and Director of CASEERI
Portland State University

Grant P. Thompson
Senior Associate
The Conservation Foundation

Victoria J. Tschinkel
Secretary
Department of Environmental
Regulation
State of Florida

STAFF

Thomas J. Kuehn, Executive Director
Energy Research Advisory Board
Department of Energy

PANEL MEMBERSHIP

Ivan L. Bennett, Chairman
Professor of Medicine
New York University Medical Center

Betsy Ancker-Johnson
Vice President
Environmental Activities Staff
General Motors Technology Center

D. Allan Bromley
Henry Ford II Professor of Physics
Yale University

George Bugliarello
President
Polytechnic Institute of New York

William D. Carey
Executive Officer
American Association for the Advancement of Science

Walter E. Massey
Director
Argonne National Laboratory

David Pimentel
Professor
College of Agriculture
Cornell University

Louis H. Roddis, Jr. (ex officio)
Chairman
Energy Research Advisory Board

Cleveland Dennard
President
Atlanta University

William T. Golden
40 Wall Street
New York, N.Y.

Norman Hackerman
President
Rice University

Charles Hitch
President Emeritus
University of California

Henry R. Linden
President
Gas Research Institute

Roland W. Schmitt
Senior Vice President
Corporate Research & Development
General Electric Company

Clifford V. Smith
Special Assistant to the Chancellor and Director of CASEERI
Portland State University

John Toll
President
University of Maryland

Executive Secretary:
Richard E. Stephens
Office of Energy Research
Department of Energy

Mary Gant
Science and Technology Affairs Staff
Office of Energy Research
Department of Energy

CONTENTS

VOLUME I

ABSTRACT xi
1. INTRODUCTION 1
1.1 Methodology 1
1.2 Additional Background 2
1.3 Structure of the Report 2
2. DOE POLICIES REGARDING UNIVERSITY SUPPORT 5
2.1 Introduction 5
2.2 Concerns and Comments 7
2.3 Findings and Recommendations 8
3. DOE MANAGEMENT AND PROCUREMENT-RELATED POLICIES IN DEALING WITH UNIVERSITIES 11
3.1 Introduction 11
3.2 Support Mechanisms and Procedures 11
3.3 Findings and Recommendations 14
4. RELATIONSHIPS BETWEEN THE DEPARTMENT'S NATIONAL LABORATORIES AND THE UNIVERSITIES 17
4.1 Introduction 17
4.2 Concerns and Comments 17
4.3 Findings and Recommendations 19
5. UNIVERSITY PARTICIPATION IN ENERGY TECHNOLOGY R&D 21
5.1 Introduction 21
5.2 Concerns and Comments 22
5.3 Findings and Recommendations 24
6. THE DOE ROLE IN THE DEVELOPMENT OF NEW PROFESSIONAL MANPOWER 25
6.1 Introduction 25
6.2 Concerns and Comments 26
6.3 Findings and Recommendations 27
7. COMMUNICATIONS BETWEEN THE DEPARTMENT AND THE UNIVERSITY COMMUNITY 29
7.1 Introduction 29
7.2 Concerns and Comments 29
7.3 Findings and Recommendations 30
8. UNIVERSITY INVOLVEMENT IN MULTIDISCIPLINARY AND INTERDISCIPLINARY RESEARCH PROGRAMS 33
8.1 Introduction 33
8.2 Concerns and Comments 33
8.3 Findings and Recommendations 34
9. CONCLUSION 37
ATTACHMENT A. DEPUTY SECRETARY'S CHARGE 39

ATTACHMENT B. SUMMARY OF DOE SUPPORT FOR UNIVERSITY ENERGY R&D 43
ATTACHMENT C. LIST OF PEOPLE WHO RESPONDED TO PANEL SURVEY 49
ATTACHMENT D. AGENDAS FOR PANEL MEETINGS 59
ATTACHMENT E. DRAFT DOE POLICY STATEMENT ON DOE-UNIVERSITY RELATIONSHIPS 67

VOLUME II

SUPPORT STUDIES PREPARED BY OAK RIDGE NATIONAL LABORATORY

1. STATISTICAL DATA 1
2. SURVEY OF RESPONSES TO DOE'S REQUEST FOR INPUT TO THE ERAB PANEL 19
3. RELATIONSHIPS BETWEEN UNIVERSITIES AND THE DOE LABORATORIES 33
4. RELATIONSHIPS BETWEEN UNIVERSITIES AND GOVERNMENT AGENCIES 51
5. NOVEL AND EXEMPLARY ROLES 81
6. SUMMARY OF RECENT STUDIES OF THE UNIVERSITY/GOVERNMENT RELATIONSHIP IN RESEARCH 115
BIBLIOGRAPHY 123
APPENDIX A. DOCUMENTS CONCERNING MINORITY S/E DOCTORATES 139
APPENDIX B. ADMINISTRATIVE OFFICES FOR ENERGY RESEARCH PROGRAMS AT UNIVERSITIES 141
APPENDIX C. THIRTY-NINE LARGE ENERGY RESEARCH CENTERS WITH ANNUAL FUNDS OF $1 MILLION OR MORE RESPONDING TO ORNL SURVEY 143
APPENDIX D. SURVEY RESPONSES 145
APPENDIX E. SURVEY RESPONDENTS 163
APPENDIX F. MERRA ACTIVITIES 173
APPENDIX G. WORK UNDERTAKEN UNDER THE AUSPICES OF THE FORD MOTOR COMPANY/UNIVERSITY JOINT RESEARCH PROGRAM 177
APPENDIX H. DOE-SPONSORED FORD/UNIVERSITY RESEARCH PROGRAM REVIEW MEETING 179
APPENDIX I. CENTER FOR CATALYTIC SCIENCE AND TECHNOLOGY: RESEARCH EQUIPMENT 181
APPENDIX J. CENTER FOR CATALYTIC SCIENCE AND TECHNOLOGY: RESEARCH ACTIVITIES 183
APPENDIX K. UNIVERSITY OF DELAWARE: CATALYSIS EDUCATION 185
APPENDIX L. EXAMPLES OF NSLS EXPERIMENTS 187

ABSTRACT

The Final Report of the University Programs Panel of the Energy Research Advisory Board responds to the Department of Energy's request to examine "the effectiveness of the Department's policies toward and working relationships with the academic community." In the course of this study, the Panel examined the entire spectrum of the Department's relationships with and programs for universities and university scientists and students. This included the direct support provided by Department programs for on-campus research and related manpower development and the indirect, but substantial, assistance provided through the Department's national laboratories to university faculty and students.

The Panel received numerous comments and suggestions from representatives of the academic community regarding their relationships with the Department. In addition, presentations were made to the Panel by senior Department program and policy staff, by representatives of the national laboratories, and by senior staff from other Federal agencies with substantial university programs. A series of in-depth case studies and assessments were also carried out on a number of past and current Departmental programs involving universities.

Based on this extensive information and related material, the Panel has identified seven major issues and concerns which require attention if the Department's relationships with the academic community are to be strengthened and improved. These issues are

- the lack of comprehensive and consistent Department-wide policies toward the involvement and support of universities in energy R&D and related programs,
- the Department's management and procurement policies and procedures related to the support and oversight of university programs,
- relationships between the Department's national laboratories and the academic community,
- participation of university scientists and students in the Department's various energy technology development programs,
- the Department's role in the development of professional-level manpower,
- communications between the Department and the academic community, and
- university involvement in multidisciplinary and interdisciplinary energy R&D.

Based on analyses of these issues, the Panel has considered and adopted a number of recommendations for the consideration of the Department designed to resolve or eliminate, wherever possible, the problems that have developed over time between the Department and the academic community. The principal recommendation of the Panel is that the Department, at the level of the Secretary, should clearly state its view of what the proper university role is in support of Departmental programs. Related to this recommendation is the need for the Department to establish an agency-wide R&D program planning process that would include opportunities for university and other scientists to contribute to the establishment of future "research agendas" and resulting priorities for each major program in the Department. Other recommendations are directed at improving the Department's policies and procedures for the award and administration of university research grants and contracts, increasing university involvement in technology-oriented R&D, and ensuring that research proposals submitted to the Department for consideration should be subjected to

comparable standards of external peer review whether the proposal is from a national laboratory or university-based group.

Finally, the Panel believes the Department's relationships with the academic community would be significantly improved if communications between Departmental staff and university officials were strengthened and expanded. Therefore, the Panel recommends that the Department consider establishing a "forum" of university presidents and other senior officials that would meet periodically with the Secretary and DOE senior staff to review mutual problems and concerns, with resulting appropriate follow-up by policy and program staff.

1. INTRODUCTION

This report was prepared in response to a request by the Deputy Secretary of Energy on November 5, 1982 (Attachment A), that the Energy Research Advisory Board (ERAB) examine the effectiveness of the Department's policy toward and working relationships with the nation's universities. The Deputy Secretary asked the Board to explore the following:

- Is the Department effectively utilizing the general capabilities of the university community in both fundamental and energy research?
- Is the Department effectively utilizing universities, vis-a-vis laboratory and private sector groups, in energy research and technology development programs?
- What responsibilities and mechanisms are appropriate for the Department in professional-level manpower development including, but not limited to, support for graduate students, postdoctoral researchers, and younger faculty members?
- What current factors, actual or perceived, foster or impede good working relationships between the Department and the academic community?
- In what ways, if any, could the Department improve the effectiveness of the working relationships between the DOE laboratories and the universities including, for example, the planning and conduct of joint research programs?
- What changes, if any, should the Department make in order to provide the most effective support of university-based energy research?

To perform the requested study, the Board established a Panel on University Programs, composed of both Board and non-Board members (list follows title page). The Panel was charged to report its findings to the full Board for review and approval prior to transmittal to the Secretary.

1.1 Methodology

1.1.1 Review

The Panel conducted a general review of the historical and existing relations between the Federal Government and the nation's universities, with particular emphasis on recent trends in support by various agencies for research and development (R&D), for collaborative programs with government laboratories and industry, and for the development of professional manpower. This material is summarized in Volume II, Chapter 4.

A specific summary of university programs supported by DOE and it predecessor agencies is included as Attachment B to Volume I.

1.1.2 Comments

Comments on DOE-university relationships were solicited by letter from

- presidents of selected universities and colleges,
- presidents of professional scientific and engineering societies,
- presidents of educational associations and consortia,
- deans of schools of engineering,
- individual university scientists and engineers with past or current working relationships with the Department, and
- directors of the Department's multiprogram national laboratories.

These requests and respondents are listed in Attachment C to Volume I, and the overall results are tabulated in Volume II, Chapter 2 and Appendix D.

1.1.3 Presentations

In addition, at several meetings, the Panel heard presentations on university programs from

- the Director of the Office of Science and Technology Policy;
- representatives of the Department of Defense (DoD), National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF);
- university presidents and research administrators;
- university scientists with support from DOE;
- DOE National Laboratories; and
- DOE senior program and policy staff.

See Attachment D for agendas of the several meetings of the Panel.

1.2 Additional Background

The Panel recognizes that energy is not a single technical, scientific or academic discipline. The areas of science and engineering important to different energy forms and sources and to conservation vary so widely that any attempt to address the Department's program as a generic issue is bound to fail. It is also important to recognize that the academic institutions capable of carrying out energy-related research vary widely in size and scope from large, graduate-oriented research universities to small, undergraduate colleges. Furthermore, a large amount of energy-relevant research is supported by other Federal agencies and by industry. This report does not assess these other efforts in detail but points out that DOE-university programs must be structured in a broad national context.

The Panel's study points up a variety of troublesome aspects of DOE's working relationships with the university community that, *unless dealt with decisively*, can erode a historic partnership that has been and is essential to the accomplishment of the Department's mission. But the overall picture is far from bleak. There have been important recent and continuing efforts in DOE to improve the relationships between the Department and the university community. Those include progress towards the improvement of DOE patent policies and procedures related to university research, the expanding use of multiyear awards for university research the initiation of a program to improve university research instrumentation, renewed emphasis on the use of facilities at the national laboratories by faculty and students for research and education, and significant steps in the initiation of research and related educational activities at some of the nation's Historically Black Colleges and Universities. In addition, the Department has had historically, and continues to have, a major impact on a number of university research and education areas, particularly in the nuclear and physical sciences and in nuclear medicine. For example, national preeminence in high-energy and nuclear physics is due in no small part to the unique and ongoing partnership among the Department of Energy, the DOE national laboratories, and the university community. The Department can take justifiable pride in its accomplishments in these fields.

1.3 Structure of the Report

Based upon a review of DOE's recent programs of support for university-based R&D and education (Attachment B); of information collected from universities, professional organizations, and the national laboratories (Attachment C); and of current information presented by the several program offices of the Department and representatives of the Office of Science and Technology Policy (OSTP), DoD, NASA, and NSF (Attachment D), seven major issues were identified as requiring attention if existing shortcomings in the Department's utilization of the nation's academic capabilities are to be corrected and the resulting improvements sustained. These are

1. the lack of comprehensive and consistent DOE-wide policies toward the involvement and support of universities in energy R&D and related programs,
2. DOE procurement policies and procedures related to the support of university programs,
3. the relationships between universities and the Department's national laboratories,
4. the participation of university scientists in DOE's energy technology development program,
5. the Department's role in the development of professional-level manpower,

6. communications between the Department and the academic community, and
7. university involvement in multidisciplinary and interdisciplinary programs.

These issues constitute the main headings of the report. Each is discussed, findings and conclusions are given, and recommendations for actions are suggested.

2. DOE POLICIES REGARDING UNIVERSITY SUPPORT

Issue: The Department lacks a consistent agency-wide policy for university involvement in energy R&D and related manpower development.

The Panel recommends that the Secretary of Energy issue a policy statement affirming the importance of university involvement in all appropriate Departmental programs and that the support of university-based research and manpower development by all Departmental programs and offices be conducted in conformity with this policy.

2.1 Introduction

2.1.1 Sources of support

Support for university-based research in the Department of Energy is provided from each of the major outlay program offices (Energy Research, Fossil Energy, Nuclear Energy, Conservation and Renewable Energy, Defense Programs, etc.). In FY 1983, 75% of DOE university research funding will be provided through the Office of Energy Research (ER). University support from other DOE programs, now minimal, has fluctuated significantly during the past few years because of changing national policies and priorities for the role of the Department in development of energy technologies. Table 2.1 summarizes direct university funding from each DOE program. In addition to this direct funding of university research by DOE programs, over $200 million of indirect support was provided to university faculty and students in FY 1982 through the Department's national laboratories (Table 2.2). This total includes an estimate of the portion of the operating costs of laboratory research facilities when they are "used" by university scientists (additional information on DOE university support may be found in both Attachment B and in Volume II).

2.1.2 Selection of performers

Each program office in the Department is responsible for carrying out its R&D programs using the most appropriate mix of performers, whether at national laboratories, at universities, or in industry, to meet particular program needs and requirements. Different approaches to this are followed by the various program offices. Some offices have assigned significant technical management responsibility for specific R&D programs to one or more of the DOE national laboratories. The laboratories in turn may contract with industrial and university researchers for elements of these assigned programs. This is the procedure, for example, in several of the reactor development programs of the Office of Nuclear Energy where national laboratories have lead mission assignments.

2.1.3 Procedures for proposals

A theoretical advantage of the present decentralized process is that there are a number of potential "homes" in the Department for the support of research in particular areas; for example, a scientist interested in pursuing materials research can contact more than one program office in the Department for review of a particular proposal, depending on the

Table 2.1. Department of Energy university R&D funding by major program office[a]

(budget outlay in millions of dollars)

Program	FY 1981 actual	University R&D funding (%)	FY 1982 estimate	University R&D funding (%)	FY 1983 estimate	University R&D funding (%)
1. Energy Research	206.8	68	205.0	79	239.1	75
2. Fossil Energy	44.5	15	19.6	8	39.9	13
3. Conservation and Renewable Energy						
Conservation	11.1		5.1		5.5	
Solar/Geothermal Energy	23.5		20.0		11.0	
Subtotal	34.6	11	25.1	10	16.5	5
4. Nuclear Energy[b]	9.1	3	2.7	1	4.4	1
5. Defense Programs	7.9	3	7.3	3	16.9	5
Total DOE:	302.9	100	259.7	100	316.8	100

[a]These totals reflect only direct awards and do not include university subcontracts or the operation of user research facilities by the national laboratories; details may not add to totals because of rounding.

[b]Includes civilian radioactive waste management R&D.

Table 2.2 Department of Energy Support for university R&D FY 1982—comparison of direct and indirect funding

Source	Funding (millions of dollars)	
	Direct	Indirect
Energy Research		
High-Energy Physics	47.1	92.0[a]
Other	157.9	6.5
Fossil Energy	19.6	NA[b]
Conservation/Renewables	25.1	NA
Nuclear Energy	2.7	NA
Defense Programs	7.3	NA
Multiprogram national laboratories		
Subcontracts		37.9
Facility use		70.3[c]
Total	259.7	206.7

[a]Includes proportion of FERMI/SLAC operating costs attributable to university research groups.

[b]NA = data not available.

[c]Includes appropriate proportion of operating costs of user facilities at laboratories attributable to university research groups.

Source: DOE and laboratory staff.

nature and focus of the project. In fact, however, inconsistent procedures for soliciting and processing proposals by the various program offices and lack of effective communication among program offices concerning applications for support have worked to the disadvantage of many university applicants. ER relies almost totally on unsolicited research proposals; other program offices consider support for university research almost entirely in conjunction with competitive solicitations; and several program offices are not prepared to consider unsolicited proposals at all.

2.1.4. Communication of DOE research interests and priorities

Responses received by the Panel from university scientists indicated particularly strong concern about this lack of procedural consistency among the various DOE program offices in support of university research and about the paucity of current information concerning the Department's research interests and priorities. Several university respondents also commented on the apparent lack of understanding by some DOE program managers of the requirements universities face in carrying out research as part of an academic program, particularly the stability and continuity required for graduate research. Notwithstanding the understandable effects of recent Administration policy changes on energy R&D programs and budgets, the constant sense of instability in the planning and conduct of energy programs has severely affected the "predictability" of university funding. There is a widespread perception that

some DOE programs were interested only in "quick fix" R&D rather than a balanced research program involving long-range, fundamental research, as well as applied research and exploratory development. It is felt many university research groups can contribute to most phases of energy R&D but are not being provided the opportunity to do so.

2.2 Concerns and Comments

The decentralization of university support to the various program offices, the varying procedures used to review and support university projects, and the lack of an agency-wide policy on the role of universities and university scientists in energy R&D have limited progressively the Department's liaison with the university community.

2.2.1 Policy on university roles in DOE programs

Based on the correspondence and presentations to the Panel, it is obvious that university scientists do not see one "Department" but many "Departments" of Energy. From the university perspective, DOE is composed of a number of seemingly autonomous R&D programs, field offices, and contractor-operated research facilities. The university perception of other Federal agencies (NSF, the various R&D organizations in DoD, NASA, and the National Institutes of Health) is substantially different. These agencies are seen to have an agency-wide and uniform appreciation of the roles and importance of universities in their respective programs and the ability to communicate their research interests and priorities in a timely fashion.

Why is the situation in DOE different? The Panel is convinced that a major reason is the lack of a coherent and clearly articulated policy regarding the appropriate roles of university scientists and engineers in DOE programs. This problem is compounded by a lack of comprehensive and timely information on DOE's R&D needs, goals, budgets, and schedules. Whereas programs in ER, particularly such "national trust programs" as High-Energy and Nuclear Physics, have formal advisory committees with significant participation by university scientists, many other DOE programs have little or no formal continuing communication or involvement with the academic community.

2.2.2 University involvement in long-range planning

One recurring theme in most of the university correspondence is concern over the general lack of involvement by university scientists in longer-range R&D planning in Department programs, including decisions on future R&D agendas for each program. This concern is related to others previously expressed in a number of reports from the Energy Research Advisory Board (ERAB) regarding the need for more comprehensive and consistent longer-range R&D planning by DOE programs. It is recognized that planning is difficult in an environment subjected to as many policy shifts and changing emphases as the Department's; nonetheless, such advance planning, including involvement in and discussion by university and other scientists of the roles to be played by each R&D performer—the national laboratories, universities, and industry—could significantly contribute to the development of stronger, more predictable relationships with the external research community.

2.2.3 Support for Historically Black Colleges and Universities

Another issue of specific concern to the Panel is DOE policy regarding support for research and manpower development programs in Historically Black Colleges and Universities (HBCUs). Both Presidents Carter and Reagan have affirmed the need to expand support for the HBCUs. All Federal agencies are supporting HBCU programs in varying degrees. The DOE support of these institutions is also decentralized, with HBCU initiatives being supported in relative isolation in each program office. Some rely on unsolicited proposals from HBCU faculty, some use competitive solicitations, and some use the national laboratories as intermediaries with the HBCUs. The Panel believes that this fragmentation of effort can actually become counterproductive to the strengthening of HBCU participation in main-

stream scientific research. Of the over 100 HBCUs, only a few are now institutionally capable of carrying out major scientific and technical research programs. DOE support should recognize this and concentrate on strengthening the research capabilities of HBCUs chosen for their scientific/technical potential.

2.2.4 Summary

The responses received from university scientists, engineers, and administrators to questions posed by the Panel indicate a high degree of dissatisfaction with the Department's energy R&D programs. The solution to these problems is *not* simply additional funding for university research. Rather, the Department needs to focus on the broader issue of how the capabilities of university faculty and students can be utilized best by the Department, in conjunction with industry and the national laboratories, to meet Departmental requirements and needs. In other words, how can the Department ensure a proper balance of effort among the major R&D performers in each phase of energy R&D?

Our principal recommendation is that the Department, *at the level of the Secretary*, must clearly state its view of the university role in Departmental programs and describe how the Department intends to strengthen and support university involvement in all appropriate activities. A suggested draft of such a policy statement and directive is included as Attachment E. Once such a statement has been developed and disseminated by the Secretary, it will be incumbent upon all DOE programs to adopt practices that ensure conformity with this policy.

2.3 Findings and Recommendations

2.3.1 Findings and conclusions

- There is no overall Departmental policy on the appropriate roles of universities in energy R&D vis-a-vis industry and the national laboratories.
- Universities have significant research and manpower development capabilities that are not being utilized by DOE.
- University researchers do not receive timely and comprehensive information about DOE program plans, interests, and needs.
- Policies and procedures within the Department for the receipt and review of research proposals from university scientists and engineers vary widely and unnecessarily.
- The lack of comprehensive and consistent longer-range R&D planning by DOE programs has led to uncertainties and confusion by university and other scientists regarding program priorities, emphases, and interests.
- The Department has not articulated a policy position on its responsibilities to support the training and preparation of the new professional-level manpower required for future energy R&D programs.

2.3.2 Recommendations

1. The Department should design and implement an agency-wide R&D program planning process to include participation by university and other scientists in decisions on the current and potential role of the major R&D performers (national laboratories, industry, universities) in each DOE program over the proposed planning period.
2. The existing system of DOE advisory panels and peer review groups should be expanded to cover all major R&D programs whether managed at Headquarters, the laboratories, or elsewhere.
3. The Department should establish a DOE-University Forum (similar to the DoD-University Forum initiated in 1982) to enable university representatives to meet regularly with the Secretary and Program Assistant Secretaries on issues concerning university participation in DOE programs (see pp. 30-31).
4. DOE support for research and related programs at the Historically Black Colleges and Universities should concentrate on strengthening the energy-related scientific and technical capabilities of a few competitively selected institutions.
5. The Department should clearly define the roles of university scientists and engineers in support of its R&D and manpower requirements and the Secretary should issue an agency-wide policy directive to

- promote involvement of university faculty and students in all appropriate DOE R&D programs;
- establish the principle that formal advice from university scientists and engineers will be incorporated into the planning and implementation of the Department's research and technology development programs;
- reaffirm the importance of unsolicited proposals from university scientists and engineers as a major means of supporting university-based R&D;
- encourage and provide incentives for interaction and collaboration in R&D among university, national laboratory, and industry scientists and engineers;
- promote participation by faculty and students at the Historically Black Colleges and Universities in Departmental R&D and related programs;
- provide that the need for the continual education or training of professionals in selected research areas should be *explicitly considered* in decisions on where to support energy R&D—at universities, at the national laboratories, or in industry;
- stress the need to commit support to university projects on a time scale that will facilitate graduate and postdoctoral involvement in DOE-sponsored R&D;
- mandate that administrative and reporting burdens on university projects be held to the minimum level consistent with the Department's financial and program oversight responsibilities; and
- designate the responsibility for oversight of university programs, including reviewing the level of university involvement and participation in planning and implementing all DOE R&D programs, to an appropriate senior official in the Department.

3. DOE MANAGEMENT AND PROCUREMENT-RELATED POLICIES IN DEALING WITH UNIVERSITIES

Issue: The Department's management procedures for R&D, including procurement, are burdensome and internally inconsistent and have not been conducive to the development of close working relationships with universities and colleges.

DOE should take all necessary steps to ensure that its management and procurement policies and procedures for R&D are uniform among the program offices, are as simplified as legally possible, and are as compatible with and supportive of university participation as are those of other Federal science- and technology-based agencies.

3.1 Introduction

The Panel's questioning of the academic community elicited extensive criticisms, suggestions, and recommendations concerning DOE's relationships with universities, covering the entire range of administrative and procurement procedures including solicitation, handling, and review of proposals; negotiation and execution of contracts and grants; and financial and technical reporting requirements.

The following excerpts from two letters written by senior university research administrators epitomize most of the communications received:

> — A recurrent theme in discussions of the university/DOE relationship is the increasing difficulty of dealing with the agency on administrative matters. The hassle factor in negotiating contracts, obtaining routine approvals and documenting expenditures has grown in AEC/ERDA/DOE much more than in other agencies. . . . The type of accountability demanded in short-term energy development projects is being extended to basic research to a greater extent at DOE than at other agencies.
>
> — DOE procurement policies are notorious for their slowness and bureaucratic complexity. No other department recommends that simple renewal proposals be submitted more than 120 days in advance of the expiration date of existing contracts. In a one-year cycle, this means that renewal documentation must be prepared on less than two-thirds the funded effort. Frequently, this is before significant results can be obtained. We are driving a car by looking out the back window.

3.2 Support Mechanisms and Procedures

To understand better how the Department's mechanisms and procedures for support of university R&D evolved to the present unsatisfactory state and to suggest corrective measures, the Panel reviewed the history of this subject in the predecessor agencies and programs that were incorporated into DOE when it was established.

3.2.1 Grant and contract mechanisms

The Atomic Energy Commission (AEC) was quite effective in supporting and administering university-based research principally through the means of a unique contract instrument now called the Special Research Contract (SRC); the SRC is a streamlined agreement, much like a grant, to reimburse universities

for the cost of basic or applied research. A relatively simple document, typically consisting of 3 to 5 pages of specific text with 20 to 25 pages of appendixes, the SRC is flexible, calls for minimum reporting, provides for advance funding when needed, and is easily renewed. (A number of university respondents noted that the SRC is even easier to administer than grants for similar projects.) AEC also pioneered the approach of delegating the negotiation, execution, and monitoring of its research awards to individual institutions to one of its field offices, leading to a single continuing point of contact for university administrators and AEC contract officials. In practice, the Chicago Operations Office became the major administrative interface between the AEC and most of the university community up until the mid-1960s.

With the establishment of the Energy Research and Development Administration (ERDA) in 1975, new research areas were added to the nuclear responsibilities of AEC, and with the transfer of these programs came additional personnel with different concepts of university research support. For example, the Solar Energy staff came predominantly from NSF, where university research was supported by grants. Staff in Fossil Energy was drawn largely from the Office of Coal Research in the Department of Interior, where cost contracts were prevalent. The Fossil Energy program staff was also accustomed to centralized procurement based in Washington, although a number of university projects were funded through the Energy Technology Centers in Pittsburgh, Morgantown, etc. Meanwhile, the basic research programs of ERDA continued to use the SRC to support university research projects. (Additional information on DOE's university-related procurement and administrative procedures may be found in Volume II, Chapter 4.)

Shortly after the establishment of DOE in 1977, a working group commissioned by Dr. Frank Press, then Director of the Office of Science and Technology Policy (OSTP), and chaired by Dr. Solomon Buchsbaum of the Bell Laboratories, reviewed the scope and quality of the new Department's basic research programs. Among other things, the group's report called attention to the relatively low level of university support and pointed out the dangers to future university involvement in DOE programs inherent in the increasing disparities in the procedures used by the various component programs of this new "conglomerate" for soliciting and reviewing university proposals and for supporting and monitoring academic research. The principal concerns of the OSTP report in this area were as follows:

> We have noted . . . that the existing DOE research is not well balanced between DOE Labs, industry and universities, with the level of university research in energy-related studies being especially meager. Accordingly, we recommend that
>
> *the budget for basic research in the universities be increased. If necessary, funds should be diverted for this purpose from the development activities or even from other parts of the basic research program.*
>
> Review and procurement procedures for basic research proposals, in many sectors of DOE, are not well organized, are overly involved, take too long and often produce considerable antagonism. This situation need not be since acceptable procedures exist within the OER and elsewhere in the government. Therefore,
>
> *quality control and rapid review-approval procedures for research proposals should be devised and adopted throughout the department.*
>
> The OER should devise review and procurement procedures for research throughout DOE, with the aim of establishing uniform, rapid, and simplified methods. Submission procedures should be well publicized. Review and approval should be accomplished within six months of submission. In general, grants rather than contracts should be used as the supporting mechanism for basic research projects.

These recommendations, despite some efforts to do so, were not implemented effectively; had they been adopted, the present report would probably have been unnecessary.

Instead, diversification continued in the Department's university procurement-related processes: some programs expanded the use of grants while others assigned lead mission responsibilities to national laboratories, which in turn subcontracted with universities for portions of these mission assignments. There

has also been a continuing delegation of responsibility for negotiating, contracting, and monitoring university awards to individual DOE Operations Offices without regard for preserving the original single point of administrative interaction for each university. This is shown in Table 3.1, which summarizes for FY 1982 the award actions taken by each of the several Operations Offices.

Table 3.1. Department of Energy university contract actions[a] for FY 1982 by procurement office

Office	Number of actions	FY 1982 obligations (thousands of dollars)
Chicago Operations	1,762	561,858
Oak Ridge Operations	622	55,868
San Francisco Operations	516	891,973
Washington Procurement	308	11,993
Albuquerque Operations	161	554,422
Idaho Operations	131	5,250
Richland Operations	104	8,366
Nevada Operations	86	11,115
Savannah River Operations	83	7,523
Others (Power Marketing Administrations, Strategic Petroleum Oil Reserve, etc.)	12	3,000
	3,785	2,111,368

[a]Includes both individual university grants/contracts and operating contracts for government-owned laboratories.

Source: DOE Assistant Secretary for Management and Administration.

The gradual blurring of DOE-university administrative contacts has occurred on a program-by-program basis: most university research awards by ER are still handled through Chicago. The Defense Programs use the Nevada and Albuquerque Operations Offices, as well as making awards through the weapons laboratories; Fossil Energy employs both the Washington procurement office and the Pittsburgh and Morgantown Energy Technology Centers for administering university research projects; the Conservation and Solar programs tend to use the San Francisco Operations Office for university projects; and, finally, many smaller education projects of ER and other program offices are handled by the Oak Ridge Operations Office. Furthermore, some field offices use SRC; others use cost contracts; and still others use the grant mechanism for support of research in universities. Small wonder that universities complain about a lack of consistency among programs and field offices in administering awards for research!

3.2.2 Proposal submission and reviews

DOE procedures prescribe that all unsolicited research proposals from university scientists and engineers should be submitted to a central location in the Washington procurement office. In practice, the broad decentralization of responsibilities for university research among Headquarters, the field Operations Offices and the DOE national laboratories has often led to confusion on the part of university scientists and administrators on just where formal proposals should be submitted.

Proposal review procedures also vary widely, ranging from external review panels, mail peer review, in-house staff review, and review by a combination of in-house staff and scientists at the national laboratories. These variations in review procedures are not adequately described by DOE in communications with academic institutions.

3.2.3 Management and reporting

Much concern was expressed about the increasing tendency in DOE to place more management and reporting requirements on university research projects. For example, several of the technology programs require monthly technical and financial reports on each project. In contrast to this approach in DOE, NSF has recently taken steps to reduce significantly the administrative burden for its university grantees through such steps as allowing grantee institutions substantial authority in administering NSF grants. This includes allowing preaward costs, transferring funds from one related NSF grant to another and unilaterally extending the expiration date of an award for up to six months. In contrast, numerous complaints were cited to the panel concerning the laborious and lengthy DOE process for seeking and receiving approval to purchase equipment, to reallocate project budgets, or to extend or renew DOE awards. This has led in a number of cases to universities having to absorb, on an internal basis, the

necessary costs to continue research programs until such time as the DOE award is executed.

3.2.4 Summary

In the final analysis, scientists, whether in universities or in other organizations, need the freedom and flexibility to carry out research in an open and supportive administrative environment. Nobody wants to have creative people spend most of their time continually justifying or rejustifying what has already been agreed to at the outset of the project between the government's technical sponsor and the university. Yet, this seems to be what has happened too often in DOE-sponsored university research. The Panel feels strongly that the Department should make strenuous efforts to reduce the "hassle level" of the administration of university research projects. At the same time, the Panel clearly understands the need for close monitoring of university projects that include applied or early demonstration type work or the operation of major research facilities. If a university research group is selected to carry out such major applied programs, it should be subject to the same reporting and administrative requirements as other contractors.

The Panel believes that the type of administrative controls applied to basic research can affect the quality of research being performed. The Panel urges the Department to explore ways to simplify and make consistent the management and administrative procedures used to support university research. These steps should reduce the diversion of time, effort, and cost away from the central purpose of carrying out advanced research. Simplifying procurement policies and procedures and reducing paperwork are not inconsistent with sound management or auditing procedures, but rather can encourage the best research efforts along with the earlier availability, understanding, and dissemination of research results. Finally, the Department's university procurement policies and procedures can influence whether or not university scientists even seek support from DOE. One respondent to the Panel survey summarized the feeling on the part of scientists at his institution regarding DOE support in the following way.

> Our faculty often prefer to seek support for basic energy-related research from other Federal agencies, particularly the Department of Defense, principally because of the more open and flexible administrative environment in the support of such research. Research carried out with DoD support, for example, may be quite relevant to energy R&D needs as, for example, in materials research, corrosion studies, control systems, etc. The loss to DOE, however, is that such faculty members are not directly involved in or oriented towards energy R&D needs. The nation may benefit as part of this process, but in at least the short term, the Department is the loser in the sense of being cut off from some of the most creative minds on university campuses.

If, as consistently stated by senior DOE program staff, it is the Department's intent to support the best qualified researchers regardless of their organizational location, then the Department's current university-oriented procurement and administrative policies and procedures must be significantly improved.

3.3 Findings and Recommendations

3.3.1 Findings and conclusions

- There are significant inconsistencies between DOE program offices in the handling and review of university research proposals.
  - — Some programs totally rely on unsolicited proposals; others do not.
  - — External peer review is used by some programs; in-house staff review (including national laboratory staff) is used by others.
- The selection of an appropriate award instrument by DOE program offices for the support of university research seems to depend more on the program's tradition and history rather than on the nature of the work being supported.
  - — Some programs use scientific research contracts to support university research; others use grants or "cost-type" contracts for similar research.
  - — Some university awards are multiyear, whereas others for similar research must be renewed annually.
  - — Award execution responsibilities are delegated by DOE to ten offices/technology

centers, with universities often having to deal with many different DOE procurement offices at the same time.

— University scientists and administrators report increasing concern over what is perceived as the growing complexity and related administrative overmanagement of DOE research awards.

3.3.2 Recommendations

1. The Department should undertake a review and evaluation of the appropriateness of the university proposal review procedures used by each major DOE program with the objective of ensuring conformity. The results of this review (and the procedures used by each program office to review university proposals) should be widely distributed in the academic community.
2. The Department should strongly reaffirm the importance to the Office of Management and Budget, the General Accounting Office, and the appropriate congressional committees of university unsolicited research proposals in the support of innovative research on longer-term problems.
3. The Department should reaffirm the policy (stated in DOE Order 4210.4) that unsolicited research proposals should be formally submitted to one central proposal clearinghouse in Washington and that universities should normally deal with only *one* field procurement office for all awards from DOE as prescribed in DOE Order 4200 (excluding, as necessary, defense-related university support or other special programs).
4. In the absence of more extensive use of grants, the Department should take concerted action to retain the special authority to use Special Research Contracts to support university research projects, and the SRC instrument should be used by *all* DOE procurement offices.
5. Multiyear research awards should be used increasingly by DOE to ensure stability and continuity in university funding.
6. The reporting and administrative requirements on university research projects should be simplified and conform to the experiences and practices of other Federal agencies (including DoD, NASA and NSF).
7. Periodic meetings should be held between senior DOE procurement and program staff and representatives of the university research administration community to exchange views on methods of simplifying the Department's university procurement and assistance policies and procedures. These discussions could be tied to the DOE-University Forum described on pp. 30–31.

4. RELATIONSHIPS BETWEEN THE DEPARTMENT'S NATIONAL LABORATORIES AND THE UNIVERSITIES

Issue: A widespread perception exists in the academic community that the Department's national laboratories have an unfair institutional advantage in obtaining DOE support in some areas.

The Panel is concerned about the difficulties that have arisen in the relationships between the Department's national laboratories and the academic community because of such concerns as the allocation of research funds by the Department and confusion over the appropriate roles of each performer in carrying out Departmental programs. The Panel strongly recommends that the Department take appropriate actions to address these difficulties and strengthen the ties between the national laboratories and the universities.

4.1 Introduction

The Department of Energy manages 50 contractor facilities that collectively employ over 50,000 scientists and engineers and receive over 50% of the Department's R&D budget, with about half of this amount for weapons R&D. Nine of these contractor facilities are classified by the Department as multiprogram national laboratories. The Department's national laboratories are federally owned and funded facilities managed and staffed by private contractors, including, in a number of cases, universities and university consortia. Research programs, particularly at the multiprogram laboratories, range in size and nature from small, project-type research in most of the basic energy science-related disciplines to large, multidisciplinary, technology-oriented research programs and major weapons R&D involving teams of scientists, engineers, and support personnel and the operation of various unique user research facilities. There is wide diversity among the individual national laboratories in terms of their mix of program responsibilities and facilities, their involvements in various phases and areas of energy R&D and, indeed, in their operational "styles" and characteristics.

The roles and missions of the Department's multiprogram national laboratories were extensively studied by ERAB in a report published in September 1982. This report recommended that the Department undertake a series of steps to improve the usefulness of the laboratories as national resources, including expanding the already significant cooperation between the laboratories and the university community in the training of scientists and engineers at laboratory facilities. The recommendations made in the laboratory study are currently under review by senior staff in the Department. The University Programs Panel did not reexamine the question of the proper roles and missions of the national laboratories but rather attempted to ascertain how the relationships between the laboratories and the university community could be strengthened and expanded.

4.2 Concerns and Comments

4.2.1 Relationships between individual scientists

The relations between the Department's national laboratories and the university community received the most intense comments

from university scientists and administrators. (These relationships and the concerns raised by university scientists/administrators regarding the national laboratories are examined in more detail in Volume II, Chapter 3.) These concerns reflected two different perspectives. First, there generally seem to be minimal problems in the relationships between individual scientists at universities and their counterparts at the national laboratories. This varies, of course, by scientific field (there is certainly no question about the very close relationships between high-energy physicists in universities and at the national laboratories.) Favorable comments regarding the laboratories were received particularly from faculty at smaller colleges, whose interactions with the laboratories often represent their only contact with advanced research.

4.2.2 Competition for DOE support

From higher up in the university hierachy, however, substantially different opinions were voiced about the national laboratories. The relationships between the Department and the external R&D community principally revolve around the allocation of money for R&D. In tight budget times there is simply not enough to go around. This is understood by all involved in energy R&D. There is, however, a widespread perception in the university community that the national laboratories, at least in certain fields, have an unfair institutional competitive advantage in receiving support from the Department. This is explained by some respondents as one result of the long-standing and historic working-level familiarity that laboratory scientists have with their counterparts in DOE. Partly because of this the funding process is perceived to be substantially easier for the laboratories than for the university community. The perception is also widespread in the university community that the different review criteria and procedures used by DOE for laboratory research proposals are different from those for university research projects. Proposals submitted by university scientists are subjected to extensive in-house and peer review (a process that normally takes at least six months), whereas the perception is that laboratory research proposals for *similar types of research* have a much easier and quicker route to follow.

4.2.3 DOE's placement and management of research facilities

The Department has recently located a number of new research facilities at the laboratories. The processes used to decide what types of new research facilities are needed and where they should be located are not generally well understood by the academic community. Several respondents cited the recent example of the Lawrence Berkeley Laboratory National Center for Advanced Materials as a case where the Department did not adequately consult with the scientific community before proceeding. Conversely, many respondents recognized and endorsed the unique roles played by the laboratories in the management of major research facilities (e.g., the National Synchrotron Light Source at Brookhaven). These facilities are directly beneficial to university faculty and students carrying out research. The laboratories are also recognized as having an important role in assisting in graduate education and training, particularly through the participation of graduate students in laboratory research programs and through the use of laboratory facilities and instrumentation.

4.2.4 Collaborative research programs

University respondents also felt that the laboratories have little or no incentive to develop collaborative research programs with university scientists (not just subcontracts). The perception is that many university/laboratory research projects tend to be on terms established by the laboratories themselves and are not *true* collaborative efforts with joint planning and implementation.

4.2.5 Laboratory institutional plans

Another widespread viewpoint in the university community is that because the laboratories are required to prepare long-range institution-wide research plans, they are able to provide the Department with early warning of laboratory interest in new or expanded research programs and facilities. Therefore, the laboratories, according to university critics, have an

"inside track" in submitting proposals to the Department for inclusion in the Department's own budget proposals.

The comments received from university scientists and administrators on this issue reflect, in part, the relative lack of information in the university community about the role, missions, and organizational procedures used by the DOE national laboratories. There is relatively little understanding in the academic community of the laboratories' activities, their means of support, their management relationship with the Department of Energy and, indeed, their entire process for the development of new research programs for review by DOE. The laboratories, after all, are federally owned and funded facilities. They are "creatures" of the Department, not the other way around. The criticisms, therefore, expressed by many university scientists on the roles of the national laboratories are more properly addressed to DOE, not the laboratories.

4.2.6 Summary

The real issue is whether the Department is properly seeking out, encouraging, and supporting all qualified researchers and research groups, regardless of their institutional affiliation, in energy R&D and related programs. The crux of this matter was summarized in a letter from the president of a major research university.

> The matter of mutual trust and predictability is also, I think, at the root of the troubling and growing perception among university faculty that the national laboratories have an unfair advantage in the competition for DOE research dollars. This is unfortunate, because the laboratories and the universities each have 'national trust' missions and each must be supported. . . . I believe that mutual trust and understanding will develop only if the universities, especially in their relationship with the national laboratories, come to view themselves as having a shared community with DOE.

The relationships involving DOE, the laboratories, and the university community are complicated, extensive, and hard to generalize. So are the potential approaches to strengthening these relationships. It is not the intent of the Panel's report to make explicit policy recommendations to DOE on the balance of funding that should be provided to either the laboratories or the universities. These are decisions that must be made first at the individual program level and then reviewed and approved at the Departmental level. In general, however, the Panel believes that DOE program and policy staff have not sufficiently understood and appreciated the different strengths and capabilities of the university community, as contrasted to those of the national laboratories, in relation to DOE program needs. The laboratory and university communities are complementary to a great extent—in research interests, the need for decentralized state-of-the-art research facilities, etc. However, there are important differences, not the least of which is the preeminent responsibility of universities for professional manpower development. The Department needs to clearly articulate the roles of the major R&D performer sectors in carrying out Departmental programs. The suggested DOE-University Policy Statement (discussed in Chapter 2 and included as Attachment E) is another step towards this articulation.

4.3 Finding and Recommendations

4.3.1 Findings and conclusions

- The Department's major multiprogram and program-dedicated national laboratories are important, often unique, national resources for advanced scientific and technical research.
- Universities have unique responsibilities in the preparation of new professional-level manpower for future R&D careers, a process that must be done in an advanced research environment.
- In accord with a previous ERAB study, the Panel agrees that the appropriate roles of the national laboratories as performers of energy R&D should be clearly defined vis-a-vis universities and industry.
- The national laboratories provide essential support to university-based research through the operation of unique, user-oriented research facilities and by providing assist-

ance in the training and preparation of students for future careers in energy R&D.

- Strong concerns have been expressed by university administrators over the perception that the national laboratories have an unfair competitive advantage over the university community in receiving support from the Department for new research and related facilities/equipment because of historic institutional ties to the Department and close working relationships with Departmental program managers.
- The lack of policy guidance from the Department has hindered the development of collaborative research programs involving university, national laboratory, and industrial researchers.

4.3.2 Recommendations

1. Research proposals submitted to the Department should be subjected to comparable standards of external peer review regardless of performer even though the mechanisms of proposal review may vary from program to program and performer to performer; the policies and procedures used by the Department to authorize and support new research work in the DOE laboratories should be summarized and widely distributed to the academic community.
2. Laboratories assigned lead mission responsibility by the Department for the management of applied research programs should be given greater discretion in the allocation of resources and in the selection of performers. The allocation of research funds should be based on a careful system of peer review that draws on the best scientific and technical advice available nationally to ensure that scientific/technical merit is the prime consideration for funding from the laboratories.
3. The Department should develop policy guidance and explicit incentives to encourage the development of collaborative research programs involving university, laboratory and industrial researchers.
4. Significantly expanded support should be provided for faculty and student research training appointments at the national laboratories, including sabbatical year-type faculty appointments and postdoctoral research.
5. Annual institutional planning-level reviews carried out at each laboratory by DOE staff should continue to include an explicit evaluation of each laboratory's relationship with and programs for university faculty and students.

5. UNIVERSITY PARTICIPATION IN ENERGY TECHNOLOGY R&D

Issue: University engineering and applied science groups are not given adequate opportunities for participation in the Department's energy technology development programs.

The capabilities of university scientists and engineers to contribute to shorter-term, applied research programs should be more adequately recognized and supported by each major technology program office.

5.1 Introduction

University funding provided through the Office of Energy Research is characterized essentially by a focus on long-range, discipline-oriented basic energy research with substantial stability of funding for each university project (ranging from 3 to 7 years per project and averaging about $90 thousand per year). Support provided through the various energy technology programs in the Department (Fossil Energy, Solar and Renewable Energy, Nuclear Energy, etc.) is characterized, in general, by a shorter-term research focus and is dominated by the need to clearly establish technical proof of concept so that follow-on work might be carried out by appropriate private sector performers.

5.1.1 Fossil Energy Program

University participation in the various energy technology programs for university research varies widely. For example, the Office of Fossil Energy has, for a number of years, sought to broaden the base of university research participation in coal conversion and utilization. One special program called the University Coal Research Program was developed for this purpose. Each year the program released a Notice of Program Interest (NPI) listing a number of research areas for university scientists. Unsolicited proposals are prepared by interested faculty and submitted to the Pittsburgh Energy Technology Center for peer review. About 70 projects are currently supported through this program. The process followed by the University Coal Research Program is a potential model for other technology programs to consider in supporting university-based technology-oriented research.

5.1.2 Nuclear Energy Program

In the Office of Nuclear Energy, out of a total $3.5 billion annual program, about $3 million per year is made available for university nuclear technology-related research. This support is provided primarily through the various national laboratories that have major programs in nuclear energy. No special programs have been developed specifically to encourage university research participation in nuclear energy. Support provided for what might be defined as classical nuclear engineering research involving faculty and students has been particularly limited from DOE. This is the type of research that is focused on conventional and improved reactor technology. In general, nuclear engineering students are involved, not in the study and development of new technical concepts, but in research on risk assessment and safety-related issues. The

Nuclear Regulatory Commission actually funds more research with university nuclear engineering departments than does the Department of Energy. These departments seem almost totally "isolated" from involvement in reactor technology R&D. The Office of Nuclear Energy has, however, made a special emphasis in the past several years to increase the number of graduate students pursuing doctoral degrees in nuclear science, nuclear engineering, and health physics. A graduate fellowship program was initiated in FY 1980 to support about 20 graduate students per year in these three areas. A similar effort is supported through the Fusion Energy Program.

5.1.3 Conservation, Solar, and Renewable Energy Programs

University involvement has also been limited in scope and nature in the conservation, solar, and renewable energy programs of the Department. A small number of university projects in conservation R&D have been supported (about 20 in FY 1983). As is the case with nuclear energy, many of the projects supported through the conservation programs have been funded through one or more of the DOE national laboratories. The solar and renewable energy programs have provided varying degrees of support for university research in most relevant fields (photovoltaics, biomass, geothermal, etc.). In prior years, many of these projects were funded through the Solar Energy Research Institute (SERI) in Colorado. Budget reductions at SERI in recent years, however, have essentially eliminated this support for university subcontracts in favor of in-house research. About 40 university awards were supported in the solar and renewable energy programs in FY 1983.

5.2 Concerns and Comments

5.2.1 Sources of support and grey-area proposals

There is a perception in the university community of a significant gap between the support for university research provided through the research programs in ER and the development-oriented support provided from the technology programs. Submitted proposals that fall in a grey area between basic research and applied research/exploratory development seem to have had significant difficulty in being funded. According to several university respondents, this situation has required them to prepare and focus their research on the specific interests and priorities of the program offices with potentially the most interest in their research. This tailoring may or may not reflect a real appreciation of the type and nature of research that would be most appropriate in each area. A number of respondents to the Panel's survey also indicated concern about the lack of support for manpower development and training in the technology programs even though industry and the Department's own laboratories have a very high demand for people who have received sound preparation in technology-oriented research.

5.2.2 Joint university-industry projects

One approach used by other Federal agencies to support technology-oriented research involving university scientists, while at the same time training graduate students in applied R&D, has been the funding of joint university-industry research projects. The NSF has been particularly active in promoting and supporting such joint activities. NASA and DoD have also supported a number of joint university-industry efforts. Such joint projects have the dual benefit of providing university faculty and students with the opportunity of learning about the specific R&D needs of industry while at the same time enhancing and expediting the application by industry of university-generated basic research concepts.

DOE has in the past supported a small number of joint university-industry projects. These have not occurred as a result of an agency-wide interest in or focus on such joint efforts but rather in response to "local" situations in various DOE program offices. DOE involvement in university-industry projects is described in more detail in Volume II, Chapter 5 and the appendixes. This includes several case studies on past and current projects. One pilot effort by DOE involving the Ford Motor Company and three universities is of particular interest to the Panel as a potential model

for similar projects. The Ford case study points out the advantages and benefits to both the industrial group and the participating universities while at the same time describing the difficulties the project had, over time, regarding support and interest from DOE. The Panel believes that the benefits of joint university-industry research in energy technology R&D are significant to all parties concerned, including DOE, and that the Department should make a concerted effort to stimulate and support such projects in the future.

5.2.3 University-based engineering research and education

The Panel was particularly concerned about the impact of DOE support on engineering research and manpower development. Therefore, deans of twenty major engineering schools (in terms of research support, number of students, etc.) were asked to comment on this and related issues and concerns. (A detailed analysis of these responses is included in Volume II, Chapter 2.) In general, the responses indicated that, except at a few locations, the resources of these schools have been clearly underutilized by DOE and that research programs have had no significant impact on the "intellectual resources" of engineering faculty and students. This underutilization was pointed out to have significantly limited the development of new talent needed to carry on future technical R&D programs. This is particularly noticeable in nuclear engineering according to survey respondents.

The general lack of support by DOE of engineering-oriented research and education exists in sharp contrast with DOE's impact on research and education in physics, chemistry, materials sciences, and other basic science fields as influenced by the ER programs. According to aggregate data from NSF, DOE does rank second in Federal agency support of university engineering R&D. Much of this funding on closer examination, however, was provided to several large "predemonstration-type" projects, such as magnetohydrodynamics and fluidized-bed combustion R&D, that were generally conducted outside of the engineering schools and departments and involved significant numbers of nonteaching researchers. The dean of one leading engineering school pointed out that DOE ranked sixth, possibly seventh, in comparison with NSF, DoD, private foundations, and others, in the support of engineering research on his campus.

Respondents pointed out that the lack of DOE support for engineering research is due essentially to two factors. One is that ER has not established a firm position on the support of engineering (applied) research vis-a-vis research in the basic sciences. The second is the perception (as noted before) in several, although not all, of the technology-oriented programs that university research can contribute little, if at all, to both short- and longer-term R&D requirements.

Within DOE, support for university-based engineering research has been provided primarily by the Fossil Energy Program and by the Engineering Research Program in the ER Basic Energy Sciences Program. This latter program supports about 20 university engineering projects each year. It has not, however, had a sufficient budget ($6.4 million in the FY 1984 budget request) to make a significant impact. Other engineering research projects supported by the various energy technology programs have been significantly affected, as already noted, as a result of overall budget reductions.

The Panel notes again that this subject has been addressed before by various review and study groups including the 1978 Buchsbaum OSTP Panel. Again, it is illustrative to cite a pertinent section of this report:

> The Panel holds the view and, we believe, key members of the DOE agree, that the OER should not have total responsibility for the management and support of all basic research within the DOE. For an efficient flow of ideas from basic research into the technology programs, the two must be closely coupled through applied research and exploratory development. The coupling must be such that the longer-term basic work is not preempted by short-term needs of the technology programs in which the basic work is embedded. Therefore, if basic research is to be an effective element of the technology programs,
>
> *it is essential that each Assistant Secretary assume responsibility for the funding of basic research that is relevant to his program objectives.*

Basic research must be supported by all of the Assistant Secretaries within their own operating budgets as integral components of their RD&D programs. The extent to which this is now done is inadequate. The needed levels of long-term basic research within the divisions performing RD&D will differ with program objectives and program status, but the research must be of significant magnitude and have sufficient quality and perspective to assure both an adequate response to short-term program-implementation goals and the vitality of the disciplinary areas crucial to the development programs.

The fact that ER now provides nearly 80% of the Department's total direct funding of university R&D means little progress has been made in achieving a proper balance of support and involvement of university researchers in technology-oriented R&D.

5.3 Findings and Recommendations

5.3.1 Findings and conclusions

- University funding from the energy technology programs is characterized by a short-term focus; unpredictable, often unstable funding; and uneven distribution by technology.
- Inadequate funding from DOE has deterred university engineering schools from helping to achieve DOE program goals and has limited the number of engineering graduate students being trained in energy technology-oriented R&D.
- There is a widespread perception in the academic community of an agency-wide lack of interest in engineering and applied science research.
- The limited support for university nuclear engineering research is of particular concern to both university nuclear engineering departments and the nuclear technology industry.

5.3.2 Recommendations

1. Each technology program office should explicitly recognize its responsibility to support university-based research related to specific technology needs. Consideration should be given by each technology program to ways in which university participation in technology R&D can be increased.
2. The Engineering Research Program in the Office of Energy Research should be significantly increased in size and scope over the next five years, including the initiation of a new program of research support for younger faculty members in engineering.
3. Support should be provided to increase the numbers of engineering/applied science students, including the use, as appropriate, of competitive graduate fellowships in selected fields.
4. Joint university-industry research and related manpower development projects should be encouraged and supported in each energy technology program.
5. Expanded support should be provided for university nuclear engineering research, perhaps coupled to joint funding with nuclear-related industrial companies.

6. THE DOE ROLE IN THE DEVELOPMENT OF NEW PROFESSIONAL MANPOWER

Issue: The Department has increasingly limited its support and funding for the training of new scientists/engineers.

The Panel recommends that the Department explicitly reaffirm its responsibilities to help ensure that sufficient numbers of highly qualified scientists and engineers are available to meet current and future national energy R&D needs.

6.1 Introduction

6.1.1 Supply of professional manpower

The question of what an adequate supply of professional manpower for energy R&D is cannot be isolated from broader national needs for scientific and technical manpower. Currently, there are major concerns in the Administration (as well as in the private sector) regarding the availability of sufficient numbers of suitably qualified scientists and engineers to meet both present and projected R&D needs. Statistics on the number of students pursuing advanced degrees in engineering are of particular concern to the R&D sector. This situation is summarized in Volume II, Chapter 1.

Other energy-related scientific/technical disciplines that are facing similar problems of enrollment declines at the graduate level include geophysics, nuclear science, radiation chemistry, and health physics. The overall scientific/technical manpower situation may be further exacerbated by the projected 25% decrease in the number of 18 to 24 year olds by the early 1990s. This means that the ratio of science and engineering students to students in other academic areas must be significantly increased by that time if only to maintain today's numbers.

6.1.2 Roles of Federal agencies in manpower development

Major responsibilities for carrying out the Federal role in professional manpower support and development clearly rests with NSF and the Department of Education. Both these agencies are developing new manpower-oriented initiatives, including support for precollege-oriented programs as well as support for college-level activities. The President's Science Advisor on numerous occasions (including a presentation to the Panel), however, has specifically stated that the Federal mission R&D agencies must also play an important, complementary role in this process.

These mission agencies have, over time, carried out their manpower development responsibilities in ways particularly suited for their own missions; for example, the National Institutes of Health has consistently provided support for large numbers of graduate fellowships in the biomedical and health-related sciences. The Department of Agriculture, through the various agricultural extension and land-grant university programs, has closely interrelated student support to agricultural research. NASA has for years maintained a special concern for ensuring adequate numbers of scientists and engineers in the aerospace-

57-279 O - 87 - 51

related fields. The DoD, through the three military services, has sponsored a number of special programs over the past several years focused on ensuring that an adequate supply of scientists and engineers will be available to carry out future defense R&D programs. For example, the Office of Naval Research has provided support each year for a small number of graduate fellowships in disciplines directly relevant to naval R&D. The stipends for these fellowships have been set at a competitive level to encourage undergraduate students to pursue advanced degrees in the various areas. In addition, all three services have supported summer research and cooperative intern programs at a number of the DoD laboratories for both high school students and undergraduate students.

DOE has similar needs for highly skilled scientific and technical specialists in all the disciplines that are the foundation of energy R&D. Future scientific and technical advances in all energy research and technology development areas will depend in large part on the availability of new and well-prepared scientists and engineers. The principal and by far the best way the Department can support the preparation of new manpower is to provide adequate funding for campus-based research projects directly involving graduate students. This approach is strongly endorsed by the Panel.

6.2 Concerns and Comments

6.2.1 DOE's role in manpower development

The DOE role in manpower development received many comments from the university community. One respondent from a major public university stated:

> the Department's responsibility for manpower development derived directly from its research mission. Since the Department bears most of the national responsibility for research needed for long-term energy technology development, it must ensure the continued availability of professionals for research since the university is the nation's sole source of energy professionals and research is the means by which they are trained. Adequate support for university research is required in order to provide for future manpower supply. The projected shortage of engineers in a number of energy fields is due in large part to the lack of [DOE] support for engineering research at universities.

Several respondents indicated concern that recent elimination of support by DOE for graduate traineeships/fellowships has impaired the ability of faculty members to recruit bright undergraduate students for participation in advanced energy research. A related issue cited is the "stop and start" problem of university funding from some DOE programs which has, at times, left graduate students "high and dry" because of the abrupt termination of a research project. A graduate student pursuing a Ph.D. degree in engineering and the applied science fields typically takes from three to six years to finish the degree. Stability must therefore be built into DOE support for university projects.

6.2.2 Support at three educational levels

As noted, the Department has been principally concerned with the training and preparation of new professional manpower through the support of graduate students on DOE research projects (primarily in the basic science disciplines of physics, chemistry, materials science, biology, and the environmental sciences). There are essentially three leverage points DOE can use in helping to increase/enhance the supply of professional-level manpower for future energy R&D programs. These are (1) at the secondary school level to encourage additional students to pursue science and engineering academic careers, (2) at the junior/senior level in college to encourage more students to pursue graduate-level degrees and, related to this, (3) at the graduate and postgraduate level to provide additional incentives for graduate students and postdoctoral researchers to become involved in energy-related advanced research.

In the past, DOE and its predecessor agencies have conducted special training programs in each of these three areas. For example, AEC initiated support for a range of training programs in the nuclear sciences for high school students and teachers. ERDA and DOE continued this practice both through the support of summer institutes for high school teachers on energy and in the preparation of instructional

materials on energy research and development for use in high school science and related courses. Support for high school teacher institutes and instructional materials, however, was discontinued in FY 1982 although some secondary school-related activities are carried out by several of the national laboratories. The Panel believes that the Department should maintain at least a modest degree of involvement in precollege-level education, perhaps with a special focus on women/minority student programs. However, this area is essentially outside the purview of the Panel's charter, and therefore no specific recommendations are made regarding precollege programs.

At the undergraduate level, about 600 undergraduate students are supported each year in summer research assignments at the national laboratories through the ER's University-Laboratory Cooperative Program. This effort is strongly endorsed by the laboratories, and there are at least five applicants for each place available in this program. At the graduate level, DOE has provided modest support for graduate fellowships through both the Fusion Energy and the Nuclear Energy Programs (about 20 graduate fellowships per year in each area.) Also, 57 graduate traineeships were supported in FY 1982 in four engineering disciplines (chemical, mechanical, petroleum, and nuclear engineering). No funds were requested by the Department to continue this targeted training effort in the FY 1983 budget request.

The Department supports approximately 350 postdoctoral researchers each year in the national laboratories, primarily in physics and chemistry. This support is decentralized, with each laboratory responsible for its own postdoctoral programs using research funding provided by individual DOE program offices. This is another area where the Department is not taking full advantage of both available resources and the essential need to keep younger scientists (those within five years of having received the Ph.D.) involved in full-time research at a time in their careers when they need to become fully established as quality researchers.

6.2.3 Summary

The Panel believes that the Department has an important responsibility in the preparation of new scientists and engineers. There are a number of potential mechanisms by which the support can be provided in addition to the funding of on-campus research. These include supporting graduate and postdoctoral fellowships in selected fields of probable relevance to future needs and expanding the use of both the physical and human resources available at the national laboratories for assisting undergraduate and graduate students. The Panel believes that the goal of the Department's manpower program should be to attract more of the best-qualified students into energy-related R&D careers. Overall, however, the focus of the Department's professional manpower efforts should be *quality, not quantity.*

6.3 Findings and Recommendations

6.3.1 Findings and conclusions

- In the past DOE has supported training of new professional-level manpower principally through the funding of university research projects involving graduate students. Such support has been uneven, however, with relatively large numbers of students supported in the basic science disciplines of physics, chemistry, etc., and far fewer students in applied science and in engineering.
- The Department has legislative authority to carry out manpower training at all educational levels, including precollege programs, but has not developed and consistently carried out programs designed to ensure adequate supplies of professional-level manpower for current and future energy R&D programs.
- DOE support for university-based research on technology-oriented problems has often been subject to abrupt program and policy changes and shifts leading to discontinuities in the support of graduate students.

- The national laboratories play important complementary roles to those of the universities in manpower development and training, but the resources of the laboratories in this area have been significantly underutilized by the Department.

6.3.2 Recommendations

1. The Department should explicitly recognize its obligation to play a significant supporting role in the overall national effort to ensure adequate numbers of highly skilled scientific and technical professionals. Given the generic nature of energy as a scientific/technical subject, DOE should ensure that support for manpower development is comprehensive across the major energy-related academic disciplines (the basic sciences, engineering, health and environmental sciences, etc.).
2. The Department should make a policy commitment to the support of graduate students on university research projects; such support should be as stable as possible.
3. The Department should initiate an agency-wide graduate and postdoctoral fellowship program to encourage students to work in areas of interest and relevance to the Department. The students supported should be given the opportunity to participate in research at the DOE national laboratories or with other contractors.
4. Support for the DOE University-Laboratory Cooperative Program should be significantly increased, particularly for undergraduate and graduate student appointments.
5. The Department should place special emphasis on the need to attract more women and minority students into the national scientific and technical manpower pool and provide support for research and related manpower development efforts at selected universities and colleges with substantial women/minority enrollments.

7. COMMUNICATIONS BETWEEN THE DEPARTMENT AND THE UNIVERSITY COMMUNITY

Issue: Universities and university scientists are inadequately informed about DOE program policies, interests, and needs; conversely, there are insufficient means by which university-based advice can be solicited/incorporated in DOE R&D program planning.

Effective two-way communication is essential to good DOE-university relationships. DOE must recognize that such communication is critical at all organizational and program levels, including the national laboratories. Particular attention is needed to strengthen the communications between senior DOE officials and their counterparts in the university community.

7.1 Introduction

All major organizations, whether in R&D or in other fields, face problems of communication internally as well as externally. DOE is no exception. Communications between DOE and the broad university research community are complicated by the multitude of channels including staff and program offices in Washington, field Operations Offices, the national laboratories and other contractors vis-a-vis individual university scientists, university administrators, and university and professional societies and associations.

7.2 Concerns and Comments

7.2.1 Nature and timing of communications

Based on the correspondence received by the Panel, it is apparent that many university scientists and administrators perceive their current communications, such as they are, with the Department as essentially a one-way process, that is, from DOE to the university community. Under many circumstances, even this flow of information seems erratic, with some DOE programs having well-established communications links (e.g., the High-Energy and Nuclear Physics Program or the Fusion Energy Program) while others are lacking these. Another common thread that runs through the correspondence is the lack of opportunity for knowledgeable university scientists to provide advice to DOE program directors at an early stage of the R&D policy formulation and planning process and thus to participate in determining the agenda for future research initiatives. This concern was addressed in Chapter 2.

Universities, however, are a diverse set of institutions as has been noted; there is also diversity among university scientists and administrators. The task of communicating *essential* and *relevant* information to the university community, therefore, requires constant imagination, flexibility, and, most importantly, continued personal contact with both bench-level scientists and senior university administrators.

7.2.2 Other Federal agency–university communications

The Panel examined the experiences of other Federal agencies in handling communications

with the university community. The National Institutes of Health has formal advisory committees that are involved in reviewing and evaluating the research programs and plans of each institute. These committees have major, in some cases total, representation of university researchers. NSF uses both the National Science Board and various other formal advisory committees that serve as communications channels between the university community and the programs within the agency.

The experiences of the DoD in communicating with universities are particularly relevant to DOE. Based on a recommendation to DoD senior management in a 1981 report prepared by the Defense Science Board, a forum of senior university and DoD officials has been established to review and discuss the full range of research-related needs and issues that affect the DoD's relationships with the universities. This forum includes a small number of university presidents and senior officials selected jointly by DoD and the Association of American Universities (AAU), with staff support provided by AAU. Periodic meetings are scheduled throughout the year, with an agenda prepared in advance and appropriate follow-up to resolve issues and questions.

The DoD forum appears to be working smoothly and has helped facilitate consultation with the university community on such key issues as export controls, foreign language study needs, and defense-related basic research requirements. The Panel believes that DOE should establish a similar forum of senior university officials able to represent the broad university community. Such a forum could perhaps initially be organized under the auspices of ERAB.

7.2.3 Summary

There are other steps that can be taken by the Department to improve the quality and focus of communications to and from the university community. These include regularly preparing and publishing an agency-wide guide to DOE-university programs (perhaps similar in format to the annual program guide prepared by NSF) and expanding the number and subject coverage of research planning workshops, conferences, etc., involving both university and other researchers. The Department also needs to improve the dissemination of the results of its sponsored research (regardless of the type of performer) to ensure that other researchers are informed of and are up-to-date on the ongoing research programs and projects funded by the Department. An example of this would be the annual reports prepared by certain DOE programs that summarize ongoing and completed research projects. The DOE Technical Information Center (TIC) in Oak Ridge is a particularly critical resource in this regard to the academic community. TIC collects and abstracts DOE-sponsored research. This information, if more widely publicized and disseminated, would be invaluable to university (and other scientists) seeking information about DOE program interests and activities especially in applied science and technology-oriented R&D. Finally, the Panel notes with approval the recent action taken by the Director of the Office of Energy Research to meet periodically on a regional basis with senior officials of major research universities during scheduled visits to the national laboratories. Other DOE senior staff members should consider developing similar mechanisms that would enable them to meet informally with their university counterparts.

7.3 Findings and Recommendations

7.3.1 Findings and conclusions

- Communications between the Department and university researchers/administrators are too decentralized and inconsistent to benefit both parties.
- The development of effective two-way communications with the academic community has been hampered by the size and complexity of the DOE system.
- Results of DOE-sponsored research, particularly in the applied science and technology development programs, have not been adequately disseminated to both the academic and the industrial research communities.
- Sustained discussions between senior DOE staff and their university counterparts are essential to resolving issues and concerns

and strengthening the DOE-university relationship.

7.3.2 Recommendations

1. Based on the demonstrated effectiveness of the recently established DoD-University Forum, DOE should establish a similar forum of university leaders to meet periodically with senior DOE staff, including the Secretary, on a range of research-related issues affecting the Department's ties with universities. ERAB could be used as an intermediary to help establish this forum.
2. DOE should improve the dissemination of information to universities about DOE program research interests, programs, needs, and facilities.
   - A comprehensive guide to DOE-university programs should be prepared and widely distributed at least every two years.
   - Staff contacts in each major DOE R&D program should be clearly designated to handle university inquiries regarding research needs and policies and procedures regarding university participation and support.
   - The activities of the DOE Technical Information Center should be expanded to include annual publication of summary abstracts of DOE-sponsored research by field, performer, and subject.
3. Increased use of temporary or other term-type appointments should be made to involve university scientists as special advisors/staff in DOE R&D programs.

8. UNIVERSITY INVOLVEMENT IN MULTIDISCIPLINARY AND INTERDISCIPLINARY RESEARCH PROGRAMS

Issue: The extensive multidisciplinary and interdisciplinary research, manpower development, and public extension/outreach capabilities of universities are underutilized by the Department.

The Panel recommends that DOE consider developing a new program initiative to take advantage of the unique resources of research-oriented universities for multidisciplinary and interdisciplinary research by establishing a program of competitive university research grants that would combine energy research manpower development and technology transfer extension focused on national and/or regional energy R&D problems.

8.1 Introduction

In previous chapters the Panel has recommended a number of ways to strengthen university participation and involvement in DOE's R&D programs. These programs generally are organized on a disciplinary basis, as in the ER Basic Energy Sciences Program, or on discrete technologies, such as light-water reactor development or biomass conversion, etc. However, most energy problems involve a variety of elements, including physical science, engineering, biological and social sciences, economics, environmental concerns, and institutional factors. In addition, energy problems often have significant regional, state, and local implications. The solution of many energy problems often requires either a multidisciplinary approach (where specialists from different disciplines pursue research in parallel on a common problem) or an interdisciplinary approach (where researchers from different disciplines work closely together on a common problem sharing their individual expertise).

8.2 Concerns and Comments

8.2.1 Current focus of DOE support

Typical of major universities is the availability of a broad range of disciplinary and subject area expertise among the faculty as well as facilities and instrumentation required for such research. Currently, however, university funding from DOE has been almost exclusively focused on support for discipline-oriented, basic energy research projects. There are relatively few examples of DOE university projects that combine a number of research tasks into one program. For the most part, such programs principally involve scientists in closely related disciplines and fields, such as corrosion research, combustion, etc. On the other hand, many of the national laboratories have large, ongoing research programs that involve teams of scientists and engineers from many different disciplines. The Panel believes it would be valuable to develop similar research programs in a number of universities for both mid- and long-term energy R&D and suggests the Department consider establishing a new university research program that would support multidisciplinary and interdisciplinary research and related activities on major energy R&D problems.

8.2.2 University outreach/extension capabilities

Another dimension of the university community currently unrecognized by DOE is the extensive outreach or extension capabilities

found in many universities. Most major universities, particularly those classified as land-grant institutions, have historically played important roles in the transfer of scientific and technical information to both general and specific audiences including industry and public agencies through a variety of formal and informal channels. The most visible and successful example of this is, of course, in agriculture. Energy use and conservation, as both a national and regional/state concern, might also benefit from this type of university expertise.

8.2.3 Programs of other Federal agencies

Programs supported by other Federal agencies would indicate a possibility of success for this type of effort for DOE. For example, the Environmental Protection Agency has supported on a *competitive basis* several large university-based interdisciplinary research efforts on both regional- and national-level environmental problems. Faculty at both the University of Illinois and Ohio State University have studied environmental problems related to energy development along the Ohio River Basin, and faculty at the University of Oklahoma carried out a major integrated scientific, technical, and policy-oriented research program on groundwater resources in the Rocky Mountain West. The NSF, beginning in the early 1970s and continuing today, has supported many problem-focused, multidisciplinary and interdisciplinary university research programs, including a major interdisciplinary effort on environmental research at the California Institute of Technology. As noted, the entire agricultural experiment station network and associated agricultural research programs at land-grant universities is another successful model of how universities can bring together teams of specialists to focus on one or more common problems with not only national but also significant regional and local implications.

8.2.4 State support for university energy-related research

The proposed program could also take advantage of and benefit from the substantial state support many universities receive for energy-related research. For example, the University of Hawaii is given by the state about $200,000 to $300,000 per year for energy research projects that are also supported by Federal and private sources. Louisiana State University received $900,000 in initial funding from the state for the development of a campus-wide energy research program. The close ties between the major universities in Michigan and the state government in energy R&D are described in a case study included in Volume II, Chapter 5. DOE, in general, has not fully recognized, or integrated its research with, the considerable interest in many states in university energy research. This suggested new program, incorporating national, regional, and state-based elements of a given energy R&D problem, could further stimulate state interest and support in energy research.

8.2.5 Summary

The Panel suggests that consideration of such a new university program (including research emphases, project selection, funding procedures, etc.) be an early agenda item for the proposed DOE-University Forum discussed in Chapter 7. However, the Panel in no way envisions a program initiative that is based solely on geographical considerations or that requires an entitlement or formula approach to the awarding of grants.

8.3 Findings and Recommendations

8.3.1 Findings and conclusions

- Some universities have substantial multidisciplinary and interdisciplinary research capabilities that can be focused on energy R&D problems of both a national and regional nature.
- Some universities have traditionally carried out significant technology transfer through such mechanisms as university extension programs, agricultural and engineering experimental stations, etc. These mechanisms may be appropriate for providing information services in conservation and renewable energy areas.
- Regionally-oriented research needs are not normally addressed by DOE programs.

- Many states have provided considerable funding for university energy R&D, but DOE, in general, has not taken advantage of this support.

8.3.2 Recommendations

1. The Department should consider the initiation of a new university research program incorporating multidisciplinary and interdisciplinary research, manpower development, and public outreach/extension focused on both national-level and regional-state R&D problems.
2. The concept of and policies/procedures for this proposed program should be discussed in the proposed DOE-University Forum.

9. CONCLUSION

It is essential to restate at this point the Department of Energy's overall policy regarding what the support of energy R&D should generally be, and that is to find and support the most qualified researchers and research groups to carry out DOE-sponsored research.

Within this context, as the Department proceeds to consider the various recommendations in this report regarding how to strengthen the Department's relationships with the university community, it is worth restating what it is that makes universities unique.

While universities are the prime performers of basic research in this country, they are also substantially involved in applied research. Universities are the source of all new scientists and engineers. University research and graduate training are interrelated and inseparable. These are the characteristics of universities that separate them from all other performers of energy R&D. It is essential that DOE managers recognize the special qualities of universities as institutions vis-a-vis the national laboratories and private industry.

The President's Science Advisor, Dr. George Keyworth II, summarized this as follows:

> As a group, American research universities are the best in the world, both in terms of producing the new knowledge that stimulates technology and in terms of producing the people who drive the innovative processes in society. . . . No other research institutions—federal laboratories, nonprofit organizations, or industrial laboratories—give so much return on investment in the long-term. No other institutions produce both knowledge and people.[1]

[1]*Science* **220**, June 10, 1983, pp. 1122-1125.

However, DOE must recognize that universities are not monolithic institutions. A university, like any other organization, is a collection of individuals. Unlike other organizations, universities are dominated by the need to provide an environment in which free intellectual inquiry and the transmission of knowledge can take place. Universities differ widely from one another in size, physical facilities, and research capabilities. There are large research-oriented universities, both public and private, where graduate research and education is the overriding interest. There are smaller colleges that are devoted to teaching, principally at the undergraduate level. Some universities are capable of carrying out major multidisciplinary and interdisciplinary research programs. Others are much more suited to the nurturing of individual scientists carrying out discipline-oriented research. Some universities have particular capabilities to address regional problems and concerns. DOE policies towards universities must recognize, encompass, utilize, and allow for this broad diversity.

To summarize, the Panel believes that the capabilities of universities as institutions devoted to advanced research and manpower development and of university scientists as individuals have, in general, not been fully recognized by or capitalized on by the Department in relation to the Department's needs. The Panel believes that this can be corrected in a relatively short time if the Department takes decisive action to resolve, *in priority fashion*, the issues and concerns discussed in this report.

ATTACHMENT A

DEPUTY SECRETARY'S CHARGE

Department of Energy
Washington, D.C. 20585

November 5, 1982

Mr. Louis H. Roddis, Jr.
Chairman, Energy Research
Advisory Board
110 Broad Street
Charleston, SC 29401

Dear Lou:

The Energy Research Advisory Board recently completed an excellent study of the Department's multiprogram laboratories. Your recommendations on ways to improve the effectiveness of these important institutions are being carefully and thoroughly considered.

National progress in fundamental research and other areas of science and engineering depends very substantially on the effectiveness of the Department's use of all available scientific and technical resources; laboratory, university and industry personnel. The Department currently provides about $300 million in direct support of university research, and about an equal amount in indirect support for activities at universities that contribute to our missions. It is essential to ensure that university research and manpower development activities are adequate, effective and consistent with the Department's missions and the needs of our energy R&D programs.

I request, therefore, that ERAB examine the broad issue of the roles and missions of universities' research and development and specifically address the effectiveness of the Department's policies toward and working relationships with the academic community. Within this framework, the Board should explore, among others, the following questions:

- Is the Department effectively utilizing the general capabilities of the university community in both fundamental and energy research?
- Is the Department effectively utilizing universities, vis-a-vis laboratory and private sector groups, in energy research and technology development programs?
- What responsibilities and mechanisms are appropriate for the Department in professional level manpower development including, but not limited to, support for graduate students, postdoctoral researchers, and younger faculty members?
- What current factors, actual or perceived, foster or impede good working relationships between the Department and the academic community.

- In what ways, if any, could the Department improve the effectiveness of the working relationships between the DOE laboratories and the universities including, for example, the planning and conduct of joint research programs?

- What changes, if any, should the Department make in order to provide the most effective support of university-based energy research?

These are only a sample of the obviously complex issues the Board may wish to address. You can be assured of the full cooperation and assistance of the Department as you plan and carry out this study. The schedule will, of course, be established by the Board in relation to other priorities. However, I would appreciate a final report by August 1983.

By copy of this letter, I am requesting the Director of the Office of Energy Research, the Assistant Secretaries and the Operations Office Managers to give you their fullest cooperation and support. Staff assistance for this study will be provided by the Office of Energy Research.

I look forward to discussing this subject with you and receiving your report and recommendation.

Sincerely,

W. Kenneth Davis
Deputy Secretary

ATTACHMENT B

SUMMARY OF DOE SUPPORT FOR UNIVERSITY ENERGY R&D

ATTACHMENT B

SUMMARY OF DOE SUPPORT FOR UNIVERSITY ENERGY R&D

Direct Funding of University R&D

The Department of Energy (DOE) is the fourth largest federal sponsor of university R&D, directly providing an estimated $317 million for university R&D in 1983. Within the DOE, the Office of Energy Research (ER) is the largest sponsor of university R&D, providing 75% of the total DOE funds for university research in FY 1983. ER administers long-range research programs, oversees the DOE national laboratories and other major performers of research, and helps to ensure adequate future manpower supplies. The office itself was specifically authorized and created as a result of a House floor amendment to the original DOE organization act in 1977. This amendment was developed primarily in response to concerns in the university research community over the lack of a central organization in the new Department responsible for long-range research.

Four major programs in ER provide the principal university support: Basic Energy Sciences, Biological and Environmental Research, High-Energy/Nuclear Physics, and Fusion.

The Basic Energy Sciences Program (BES) is the primary supporter of long-range, basic energy-related research. BES directly provided about $55 million in current dollars (25% of its budget) to university R&D in 1981 and 1982. BES programs support approximately 1200 individual research projects—each selected on the basis of scientific merit, relevance to BES long-range goals, and contribution to energy R&D. Although a large proportion of BES funds goes to the national laboratories (about 68% in 1983), a significant portion of the laboratory funds indirectly supports university R&D (this is discussed further in a subsequent section).

The Office of Health and Environmental Research (OHER) supports fundamental and applied research, through the Biological and Environment Research Program, to investigate the long-term health and ecological effects associated with energy technology development. The 1981 and 1982 university funding levels from OHER were $48 million and $33 million in current dollars, respectively. These figures represent approximately 20% of the total OHER budget. About 240 individual university research projects were supported in FY 1982. Funding is also provided for seven on-campus research laboratories that carry out large, multidisciplinary research programs. Both BES and OHER rely on unsolicited research proposals for support for university research. Tables B.1 and B.2 summarize funding provided by BES and OHER to universities, national laboratories, and other performers.

The High-Energy/Nuclear Physics Programs provided $67 million and $78 million in current dollars to university R&D in 1981 and 1982, respectively. However, a much higher level of university support is provided by the High-Energy Physics Program through the use of large particle accelerators and experimental facilities at the Stanford Linear Accelerator, Fermilab, and Brookhaven National Laboratory. Overall, between two-thirds and three-fourths of the high-energy physics research at the laboratories is performed by university research teams and can be considered as indirect university support. The High-Energy Physics Program included direct funding to provide partial support for about 180 research groups at approximately 90 universities. The

Table B.1. Comparison of university and national laboratory funding by major programs FY 1983 (estimate)

(budget activity in thousands of dollars)

Basic Energy Sciences Program	National laboratories[a]	Universities	Other	Total
Nuclear Sciences	21,628	7,880	1,136	30,644
Materials Sciences	85,935	21,192	1,573	108,700
Chemical Sciences	47,184	17,500	5,316	70,000
Eng., Math., and Geosciences	17,235	11,875	1,940	31,050
Advanced Energy Projects	1,405	2,690	4,205	8,300
Biological Energy Research	1,965	7,078	457	9,500
Total	175,352	68,215	14,627	258,194
	68%	26%	6%	100%

[a]Laboratory funding includes significant support for university scientists who use laboratory facilities for research.

Source: Office of Energy Research, Department of Energy.

Table B.2. Comparison of university and national laboratory funding by major programs FY 1983 (estimate)

(budget activity in thousands of dollars)

Health and Environmental Research Program	National laboratories[a]	Universities	Other	Total
Human Health Research	8,044	2,831	14,815	25,690
Health Effects Research	32,892	13,743	9,440	56,075
Environmental Research	12,979	8,901	3,560	25,440
Physical and Technological Research	17,603	4,266	7,263	29,132
Carbon Dioxide Research	3,738	632	4,630	9,000
Health and Environmental Risk Analyses	1,070	465	215	1,750
Nuclear Medicine Applications	10,976	5,490	2,034	18,500
Total	87,302	36,328	41,957	165,587
	53%	22%	25%	100%

[a]Laboratory funding includes significant support for university scientists who use laboratory facilities for research.

Source: Office of Energy Research, Department of Energy.

Nuclear Physics Program provided 25% of its total budget for university research programs and accelerator laboratories at Duke University, the Massachusetts Institute of Technology, Texas A&M University, the University of Washington, and Yale University. The Program directly supports 75 university user groups who perform their research at the DOE national facilities or at their home universities.

Other university-related programs supported by ER include the University Reactor Fuel Assistance Program (which provides fuel for university nuclear reactors), the Manpower Assessment Program (which carries out energy-related manpower supply/demand studies), and the Prefreshman Engineering Program (which is directed at providing instructional assistance to women and minority students in high school who are interested in pursuing engineering at the college level).

The Fusion Energy Program directly sponsored $32 million in current dollars for university R&D in both 1981 and 1982. The goal of this program is to develop the technology for

safe, economic, and environmentally acceptable use of fusion power for electrical generation and to develop other applications for the use of the fusion process. Funding is provided to individual university researchers and to the large university-based facilities at Princeton and the Massachusetts Institute of Technology. The Program typically supports 80 university projects including the large university research laboratory project. Most of the awards are based on unsolicited proposals that have been reviewed for their merit.

The energy technology program offices of DOE (Fossil Energy, Conservation and Renewable Resources, etc.) provide support for the further development of their respective energy technology (e.g., predemonstration) programs. The projects supported by these programs are fewer in number, larger in size, and more applied in scope than those supported by ER. Support by the technology program offices for university research is generally based on competitive solicitations. Recent budget reductions in these programs are reflected in the university funding levels for 1981 and 1982: Fossil Energy—$45 million and $20 million, and Nuclear Energy and Defense—$17 million and $10 million, respectively. Regarding the allocation of funds by the various technology offices to the national laboratories, the Fossil and Nuclear programs provided about 10% and 75%, respectively, in FY 1983 to the national laboratories or other operating contractors.

Manpower development and training

The AEC/ERDA/DOE have not had a direct statutory role in manpower development. However, early in the AEC program it was determined that the agency had a special responsibility to encourage young people to enter nuclear science and related energy fields for future careers. Therefore, in 1948 the AEC began providing support for graduate traineeships and fellowships in accordance with its mission. The ERDA and DOE have adopted similar approaches toward manpower development, even though actual funding mechanisms for the programs have changed. Within DOE, ER has been assigned the principal task of ensuring adequate supplies of manpower to meet the nation's needs.

DOE supports approximately 5000 graduate students and additional numbers of faculty per year through the various research and training programs offered at the national laboratories. These programs include the University-Laboratory Cooperative Program, which supports approximately 2000 faculty and students per year. These programs benefit both university faculty and students by providing invaluable training and research opportunities and benefit laboratory staff by providing invaluable interactions. In presentations before the Panel, representatives of the University-Laboratory Cooperative Program contractors (Argonne National Laboratory, Associated Western Universities, Brookhaven National Laboratory, and Oak Ridge Associated Universities) noted that the various programs have both the capacity and the desire to host at least twice the number of participants, if additional funding were available.

Strong emphasis is also placed by DOE on the important adjunct roles played by the national laboratories in education and manpower development. Thus, DOE and the laboratories offer several programs to enhance university research and manpower development efforts. One such program is the University of Tennessee/Oak Ridge National Laboratory Graduate School of Biomedical Sciences. The school is nationally recognized and offers training at the laboratory and job placement upon completion of the degree. One effort common to all the laboratories is that laboratory staff serve as adjunct faculty to various universities and/or participate in lecture/seminar series at universities. Several new university-related programs are now offered through the national laboratories, including joint programs with minority colleges, distinguished visitor and distinguished scientist programs, and laboratory fellowship programs. DOE has also initiated efforts through the laboratories to enhance high school education in science and mathematics. The DOE funding for all of these efforts is approximately $5 million per year. It should be noted that the DOE funding for these programs has also not been tabulated into the $200 million indirect support as men-

tioned above. Therefore, the total indirect DOE funding to universities is probably at least three-fourths of the direct DOE funding ($273 million in current dollars) for 1982.

Facilities and instrumentation support

Historically, support of specialized university research facilities and instrumentation (nuclear research and training reactors, particle accelerators, etc.) has been an important effort in the Department. Between 1970 and 1980, DOE support of R&D Plant and Instruction Facilities increased from $13.8 million to $21.5 million, representing a 56% increase. Again, the DOE provides additional significant indirect support for facilities and instrumentation at the national laboratories for university staff use. The Department also has a Used Equipment Program, which provides excess research equipment to the academic community (although the program is limited to instrumentation valued at between $300 and $10,000). Finally, a new program is being developed as part of an interagency effort coordinated by NSF. The DOE FY 1984 budget includes $4 million for university research instrumentation support that will be used to purchase equipment ranging in cost from about $100,000 to about $800,000.

Indirect Funding Through the DOE National Laboratories

The Department provides additional support to university R&D through its contractors by means of subcontracts and by providing access to user facilities at the DOE national laboratories [including the nine multiprogram laboratories (MPLs) and the large accelerators]. These DOE activities represent significant but "hidden" support for university research; this support, which has grown rapidly, totaled over $200 million in FY 1982. In fact, university subcontracting through the MPLs alone totaled $37.9 million in FY 1982. The amount of subcontracting to universities varies widely among the various MPLs from 0.7% to 11% of their DOE (nondefense) operating budgets. In addition to subcontracts, large numbers of university faculty members receive consulting subcontracts for research activities at the national laboratories; however, all the funds for these consulting subcontracts are not included in the above total.

DOE user facility support totaled $70.3 million in FY 1982; this figure is based on estimates of the proportion of the total facility operating budget that actually went to support university research. The DOE offers these programs because of the national need for research conducted at these expensive facilities.

Most of the DOE user facilities are made available at no or minimal cost to the user, as long as the research is not proprietary. For example, there is no charge for use of seven of Argonne's eleven major user facilities. However, Argonne received 120 proposals for experimental work on the Intense Pulsed Neutron Source in FY 1982: this is far more work than could possibly be accommodated even if the device were run 24 hours per day for an entire year. The other laboratories report similar experiences.

Overall the major user facilities funded by BES average 57% use by university staff. This does not include the proportion of Ames and Lawrence Berkeley Laboratory staff who have joint faculty appointments with their host universities. The new facilities such as Brookhaven's National Synchrotron Light Source and Sandia's Combustion Research Center will become increasingly important to university researchers. In recent years the Department has placed strong emphasis on the development and operation of new user facilities at the laboratories.

Finally, additional indirect funding is provided through the national laboratories and DOE contractors for manpower development and training. However, the overall funding levels for these programs is not known, and as a result, this type of support to universities is not included in the above-mentioned $200 million that DOE provides indirectly to universities.

ATTACHMENT C

LIST OF PEOPLE WHO RESPONDED TO PANEL SURVEY

ATTACHMENT C

LIST OF PEOPLE WHO RESPONDED TO PANEL SURVEY

Almodovar, Ismael
President
Universidad de Puerto Rico
San Juan, Puerto Rico 00936

Anderson, Duwayne M.
Dean
Natural Sciences and Mathematics
State University of New York at Buffalo
Buffalo, New York 14260

Anderson, Wayne
Department of Electrical and Computer Engineering
State University of New York at Buffalo
Buffalo, New York 14260

Ansell, George S.*
Dean
School of Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Antal, Michael J. Jr. (2 responses)†
Hawaii Natural Energy Institute
University of Hawaii at Manoa
Honolulu, Hawaii 96822

Baldwin, Donald R.
Assistant Provost, Graduate School
University of Washington
Seattle, Washington 98195

Balluffi, R. W.†
Department of Materials Science and Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Baruch, Sylvia
Assistant Provost
Elmer Holmes Bobst Library
New York University
New York, New York 10012

Beer, J. M.†
Department of Chemical Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Bell, Dennis D.
President
East Stroudsburg State College
East Stroudsburg, Pennsylvania 18301

Berl, W. G.
Applied Physics Laboratory
The Johns Hopkins University
Laurel, Maryland 20707

Blankenhorn, P. R.
The Pennsylvania State University
University Park, Pennsylvania 16802

Bockris, J. O'M.†
Department of Chemistry
Texas A&M University
College Station, Texas 77843

Boudart, Michel†
Department of Chemical Engineering
Stanford University
Stanford, California 94305

Brink, G. O.
Department of Physics
State University of New York at Buffalo
Buffalo, New York 14260

Brodie, H., Keith H.[1] and Pearsall, G. W.[2]
[1]Chancellor
[2]Dean, School of Engineering
Duke University
Durham, North Carolina 27706

Brophy, James J.
Chairman-Elect
Associated Western Universities, Inc.
Salt Lake City, Utah 84111

Bullard, Clark
Director
Office of Energy Research
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Carbon, Max C.
Chairman
Nuclear Engineering Department
University of Wisconsin
Madison, Wisconsin 53706

*Response to Dean Survey
†Response to Scientist Survey

Carley, C. T.
Chairman
Mechanical and Nuclear Engineering Department
Mississippi State University
Mississippi State, Mississippi 39762

Carpenter, Thomas G.
President
Memphis State University
Memphis, Tennessee 38152

Chen, Francis F.
Electrical Engineering Department
University of California, Los Angeles
Los Angeles, California 90024

Chung, Paul M.
Dean
College of Engineering
University of Illinois at Chicago
Chicago, Illinois 60680

Coberly, C. A.*
Executive Directory
Engineering Experiment Station
University of Wisconsin-Madison
Madison, Wisconsin 53706

Comstock, Dale R.
President
NORCUS Board of Directors
Joint Center for Graduate Study
Richland, Washington 99352

Conn, Robert W.
School of Engineering and Applied Science
University of California
Los Angeles, California 90024

Corn, Morton
Director
School of Hygiene and Public Health
The Johns Hopkins University
Baltimore, Maryland 21205

Cunningham, Richard G.
Vice President, Research and Graduate Studies
The Pennsylvania State University
University Park, Pennsylvania 16802

Dacey, G. C.
President
Sandia National Laboratories
Albuquerque, New Mexico 87185

Dawson, John M.†
Director
Center for Plasma Physics and Fusion Engineering
University of California
Los Angeles, California 90024

Dean, Nathan W.
Assistant Vice President for Research
The University of Georgia
Athens, Georgia 30602

Denno, K.
Engineering Department
New Jersey Institute of Technology
Newark, New Jersey

Dorfan, David E., Heusch, Clemens A., and Seiden, Abraham
Santa Cruz Institute for Particle Physics
University of California
Santa Cruz, California 95064

Drucker, D. C.*
Dean
College of Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Dunn, William A.
College of Engineering
The Pennsylvania State University
University Park, Pennsylvania 16802

Eckhoff, N. Dean
Chairman
Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

Eichholz, Geoffrey G.
School of Nuclear Engineering and Health Physics
Georgia Institute of Technology
Atlanta, Georgia 30332

Eustis, R. H.†
Mechanical Engineering Department
Stanford University
Stanford, California 94305

Faw, Richard E.
Chairman
Education Division
American Nuclear Society
LaGrange Park, Illinois 60525

Felling, William E.
Director
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

Flawn, Peter T.
President
The University of Texas at Austin
Austin, Texas 78712-7389

Flynn, George W.
Department of Physics
Columbia University
in the City of New York
New York, New York 10027

*Response to Dean Survey
†Response to Scientist Survey

Fonkin, G. R.
Vice President
The University of Texas at Austin
Austin, Texas 78712

Fordham, Christopher C. III
Chancellor
The University of North Carolina
Chapel Hill, North Carolina 27514

Forman, J. Charles
Executive Director
American Institute of Chemical Engineers
New York, New York 10017

Gaddy, O. L.
Department of Electric Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Gallagher, Richard H.*
Dean
College of Engineering
The University of Arizona
Tucson, Arizona 85721

Gardner, David P.
President
The University of Utah
Salt Lake City, Utah 84112

Garrity, Donald L.
President
Central Washington University
Ellensburg, Washington 98926

Gear, C. W.
Department of Computer Science
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Gee, E. Gordon
President
West Virginia University
Morgantown, West Virginia 26506

Giamatti, A. Bartlett
President
Yale University
New Haven, Connecticut 06520

Glimm, James
Courant Institute of Mathematical Sciences
New York University
New York, New York 10012

Goldberg, Milton
Executive Director
Council on Governmental Relations
Washington, D.C. 20036

Grad, Harold
Courant Institute of Mathematical Sciences
New York University
New York, New York 10012

Gray, Paul E.
President
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Greenberg, Ann H.
Office of Sponsored Programs
New York University
New York, New York 10003

Hahn, O. J.
Dean
College of Engineering
University of Kentucky
Lexington, Kentucky 40506-0046

Halvorson, Harlyn O.
Chairman
Public and Scientific Affairs Board
American Society for Microbiology
Washington, D.C. 20006

Hancock, John C.*
Dean
Schools of Engineering
Purdue University
West Lafayette, Indiana 47907

Hansen, Robert S.
Director
Ames Laboratory
Iowa State University
Ames, Iowa 50011

Harper, Judson M.
Vice President for Research
Colorado State University
Fort Collins, Colorado 80523

Harris, Stewart
Dean
College of Engineering and Applied Sciences
State University of New York at Stony Brook
Long Island, New York 11794

Hartnett, James P.
Secretary
Midwest Laboratories Energy Consortium
Chicago, Illinois 60680

Hickok, Robert L.†
Plasma Dynamics Laboratory
Rensselaer Polytechnic Institute
Troy, New York 12181

*Response to Dean Survey
†Response to Scientist Survey

Hill, George R.
Department of Chemical Engineering
The University of Utah
Salt Lake City, Utah 84112

Holland, J. Read
Director
School of Mines and Energy Development
The University of Alabama
University, Alabama 35486

Hubbard, H. M.
Director
Solar Energy Research Institute
Golden, Colorado 80401

Hughes, Robert E.
President
Associated Universities, Inc.
Washington, D.C. 20036

Jain, Piyare L.
Department of Physics and Astronomy
State University of New York at Buffalo
Buffalo, New York 14260

Jester, W. A.
The Pennsylvania State University
University Park, Pennsylvania 16802

Jones, Lawrence W.
Chairman
Department of Physics
The University of Michigan
Ann Arbor, Michigan 48109

Jordan, A. G.*
Dean
Carnegie Institute of Technology
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

Keenan, Boyd
Department of Political Science
University of Illinois at Chicago
Chicago, Illinois 60680

Kerr, William (2 responses)*
Director
Office of Energy Research
The University of Michigan
Ann Arbor, Michigan 48109

Klevans, E. H.
College of Engineering
The Pennsylvania State University
University Park, Pennsylvania 16802

Knoll, Glenn F.
Chairman
Department of Nuclear Engineering
The University of Michigan
Ann Arbor, Michigan 48109

Koester, Robert J.
Director
Center for Eergy Research/Education/Service
Ball State University
Muncie, Indiana 47306

Kurland, R. J.
Department of Chemistry
State University of New York at Buffalo
Buffalo, New York 14260

Larson, Charles F.
Executive Director
Industrial Research Institute, Inc.
New York, New York 10017

Lattman, L. H.*
Dean
College of Engineering
The University of Utah
Salt Lake City, Utah 84112

Lax, Peter D., and Kalos, Malvin H.
Courant Institute of Mathematical Sciences
New York University
New York, New York 10012

Lear, W. Edward
Executive Director
American Society of Engineering Education
Washington, D.C. 20036

Lederman, Leon M.
Director
Fermi National Accelerator Laboratory
Batavia, Illinois 60510

Levenson, Ruth A.
Associate Provost for Special Projects
Columbia University in the City of New York
New York, New York 10027

Levine, S. H.
Department of Electrical Engineering
The Pennsylvania State University
University Park, Pennsylvania 16802

Levy, Edward K.
Director
Energy Research Center
Lehigh University
Bethlehem, Pennsylvania 18015

Lieberman, Gerald J.
Vice Provost and Dean of Graduate Studies and Research
Stanford University
Stanford, California 94305

*Response to Dean Survey

Liu, Henry
Department of Civil Engineering
University of Missouri-Columbia
Columbia, Missouri 65211

Loeb, Lawrence A.
Director
Joseph Gottstein Memorial Cancer
Research Laboratory
University of Washington
Seattle, Washington 98195

Luboff, Jay
Director
Western Rssources Center
University of Washington
Seattle, Washington 98105

Lunt, O. R.
Laboratory of Biomedical and
Enviromental Sciences
University of California, Los Angeles
Los Angeles, California 90024

Martin, Ross J.
Director
Engineering Experiment Station
University of Illinois at
Urbana-Champaign
Urbana, Illinois 61801

Menzel, David W.†
Director
Skidaway Institute of Oceanography
University System of Georgia
Savannah, Georgia 13687

Merzbacher, Eugen
Department of Physics and Astronomy
The University of North Carolina
Chapel Hill, North Carolina 27514

Mintzer, David
Vice President for Research and Dean
of Sciences
Northwestern University
Evanston, Illinois 60201

Monteith, Larry K.*
Dean
School of Engineering
North Carolina State University
Raleigh, North Carolina 27650

Muan, Arnulf
The Pennsylvania State University
University Park, Pennsylvania 16802

Muntzing, L. Manning
President
American Nuclear Society
LaGrange Park, Illinois 60525

Mutmansky, Jan M.
The Pennsylvania State University
University Park, Pennsylvania 16802

Navratil, Gerald A.
Department of Applied Physics
and Nuclear Engineering
Columbia University in the City
of New York
New York, New York 10027

Neel, James V.†
Department of Human Genetics
The University of Michigan
Ann Arbor, Michigan 48109

Newkome, George R.
Associate Executive Director
Center for Energy Studies
Louisiana State University
Shreveport, Louisiana 71105

Nowick, Arthur S.
Columbia University
New York, New York 10027

O'Neill, R. R.*
Dean
School of Engineering and Applied
Sciences
University of California, Los Angeles
Los Angeles, California 90024

Olesen, D. E.
Director
Battelle Memorial Institute
Pacific Northwest Laboratories
Richland, Washington 99352

Oliver, Robert M.*
Associate Dean for Research and
Development
College of Engineering
University of California
Berkeley, California 94720

Overberger, Charles G.
Vice President for Research
The University of Michigan
Ann Arbor, Michigan 48109

Page, Robert H. (2 responses)*
Dean
College of Engineering
Texas A&M University
College Station, Texas 77843

*Response to Dean Survey
†Response to Scientist Survey

Payne, D. A.
Department of Ceramic Engineering
University of Illinois at
Urbana-Champaign
Urbana, Illinois 61801

Peltason, J. W.
President
American Council on Education
Washington, D.C. 20036-1193

Pitts, James N. Jr.[1]
Director
Statewide Air Pollution Research
Center
University of California
Riverside, California 92521

Pope, Martin
Department of Chemistry
New York University
New York, New York 10003

Preston, Anne (for J. V. Neel)
Department of Human Genetics
The University of Michigan
Ann Arbor, Michigan 48109

Putnam, Allan R.
Director
American Society for Metals
Metals Park, Ohio 44073

Ray, John D.
Chairman
Department of Mechanical
Engineering
Memphis State University
Memphis, Tennessee 38152

Reagor, A. Simone
Director for Research Administration
Office of Financial Systems
Harvard University
Cambridge, Massachusetts 02138

Reese, Jack E.
Chancellor
The University of Tennessee
Knoxville, Tennessee 37996-0150

Reethof, Gerhard
The Pennsylvania State University
University Park, Pennsylvania 16802

Renfrew, Clinton A.
Department of Engineering and
Technology
Norwich University
Northfield, Vermont 05663

Rennie, Donald W.
Vice President for Research and
Graduate Studies
State University of New York at
Buffalo
Buffalo, New York 14260

Roaden, Arliss L.
President
Tennessee Technological University
Cookeville, Tennessee 38501

Rosenzweig, Robert M.[1] and
Clodius, R. L.[2]
President
[1]Association of American Universities
[2]National Association of State Universities
and Land-Grant Colleges
Washington, D.C. 20036

Rosse, Cornelius
Department of Biological Science
University of Washington
Seattle, Washington 98195

Rossi, Herald H.
Director
Department of Radiology
College of Physicians and Surgeons
Columbia University
New York, New York 10032

Rowland, F. S.[1]
Department of Chemistry
University of California
Irvine, California 92717

Russell, T. W. F. and Colburn, A. P.
Director
Institute of Energy Conversion
University of Delaware
Newark, Delaware 19711

Russell, Virginia
American Association of State Colleges
and Universities
Washington, D.C. 20036

Samios, N. P.
Director
Brookhaven National Laboratory
Upton, Long Island, New York 11973

Saxon, David S.
President
University of California
Berkeley, California 94720

[1]Response to Dean Survey
[1]Response to Scientist Survey

Scattergood, Darrell M.
Department of Physics
University of Washington
Seattle, Washington 98195

Schuler, Robert H.†
Director
Radiation Laboratory
University of Notre Dame
Notre Dame, Indiana 46556

Scott, Alexander R.
Executive Director
The Metallurgical Society of AIME
Warrendale, Pennsylvania 15086

Shewmon, Paul†
Chairman
Department of Metallurgical Engineering
The Ohio State University
Columbus, Ohio 43210

Shupe, John W.
Director
Hawaii Natural Energy Institute
University of Hawaii at Manoa
Honolulu, Hawaii 96822

Sinisgalli, Allen J.
Director
Office of Research and Project Administration
Princeton University
Princeton, New Jersey 08544

Smerko, Robert G. (for University Chemistry faculty)
Director
Department of Public Affairs
American Chemical Society
Washington, D.C. 20036

Smerko, Robert G.
Director
Department of Public Affairs
American Chemical Society
Washington, D.C. 20036

Somasundaran, P.
Columbia University
New York, New York 10027

Sovern, Michael I.
President
Columbia University
New York, New York 10027

Spinrad, Bernard I.
Chairman
Department of Nuclear Engineering
Iowa State University
Ames, Iowa 50011

Stelson, T. E.*
Vice President for Research
Georgia Institute of Technology
Atlanta, Georgia 30332

Stiles, Alvin B.†
Center for Catalytic Science and Technology
University of Delaware
Newark, Delaware 19711

Stoecker, W. F.
Department of Mechanical Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Street, Robert L.*
Associate Dean of Research
School of Engineering
Stanford University
Stanford, California 94305

Street, William B.*
Associate Dean
College of Engineering
Cornell University
Ithaca, New York 14853

Telionis, Demetri
Department of Engineering Science and Mechanics
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Thilly, William G.†
Department of Nutrition and Food Science
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Thomas, Robert J.†
School of Electrical Engineering
Cornell University
Ithaca, New York 1485.

Tobias, Charles W.†
Department of Chemical Engineering
University of California
Berkeley, California 94720

Tombrello, T. A.†
Department of Physics
California Institute of Technology
Pasadena, California 91125

Ts'o, Paul O. P.†
Director
Division of Biophysics
The Johns Hopkins University
Baltimore, Maryland 21205

*Response to Dean Survey
†Response to Scientist Survey

Tsoulfanidis, Nick
Chairman
Nuclear Engineering Department
University of Missouri at Rolla
Rolla, Missouri 65401

Trefonas, Louis M.
Vice President for Research and
Dean of Graduate Studies
University of Central Florida
Orlando, Florida 32816

Turinsky, Paul J.
Chairman
Department of Nuclear Engineering
North Carolina State University
Raleigh, North Carolina 27650

Unklesbay, A. G.
Director
American Geological Institute
Falls Church, Virginia 22041

Vandiver, Frank E.
President
Texas A&M University
College Station, Texas 77843

Vandiver, Frank E. (for university faculty)
President
Texas A&M University
College Station, Texas 77843

Wang, C. H.
Director
Radiation Center
Oregon State University
Corvallis, Oregon 97331

Wasan, D. T.†
Chairman
Department of Chemical Engineering
Illinois Institute of Technology
Chicago, Illinois 60616

Watkins, Lloyd I.
President
Illinois State University
Normal, Illinois 61761

Weisman, Joel
Department of Chemical and
Nuclear Engineering
University of Cincinnati
Cincinnati, Ohio 45221

Weiss, Malcolm A.
Director
Energy Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts, 02139

Weller, Sol W.
Department of Chemical Engineering
State University of New York at
Buffalo
Buffalo, New York 14260

Wenninger, Eugene P.
Dean
Kent State University
Kent, Ohio 44242

Wharton, James H.
Chancellor
Louisiana State University
Baton Rouge, Louisiana 70803

Williams, Charles E.
Manager
Idaho Operations Office
Department of Energy
Idaho Falls, Idaho 83401

Wimberly, C. Ray
Dean
College of Engineering
Louisiana Tech University
Ruston, Louisiana 71272

Witzig, Warren F.
Chairman
Nuclear Engineering Department
The Pennsylvania State University
University Park, Pennsylvania 16802

Wolman, M. Gordon
Chairman
Department of Geography and
Environmental Engineering
The Johns Hopkins University
Baltimore, Maryland 21218

Yang, Edward S.
Department of Electrical Engineering
Columbia University in the City of
New York
New York, New York 10027

Zaborszky, John†
Chairman
Department of Systems Science and
Mathematics
Washington University
Saint Louis, Missouri 63130

Zacharias, Donald W.
President
Western Kentucky University
Bowling Green, Kentucky 42101

---

*Response to Dean Survey
†Response to Scientist Survey

ATTACHMENT D

AGENDAS FOR PANEL MEETINGS

University Programs Panel
Energy Research Advisory Board
Agenda

20 January 1983
Forrestal Building
Room 8E-089

9:00	Convene Introduction of Members and Staff Opening Remarks	Ivan Bennett Chairman
9:15	Current Federal Policies/Programs Regarding University R&D University Research and Development	George Keyworth II Director, Office of Science and Technology Policy Executive Office of the President
10:00	Review of DOE University R&D Programs	Alvin Trivelpiece Director, Office of Energy Research
11:00	Administrative Items	Mary Gant Joan Snodderly ERAB Staff
11:15	Discussion of Issues to Be Considered in Reports	Ivan Bennett
12:00	Lunch	
1:15	Continued Discussion of Issues	Ivan Bennett
2:00	Status Report and Possible Studies	Colin West Oak Ridge National Laboratory
2:30	Discussion of Future Meeting Schedule and Agenda	Ivan Bennett
2:45	Break	
3:00	Review of Department of Defense University R&D Programs	Leo Young Director Research and Technical Information, DOD
3:30	Review of NASA University R&D Programs	Hans Mark Deputy Administrator, NASA
5:00	Adjourn	

62

University Programs Panel
Energy Research Advisory Board
Agenda

February 14, 1983
Forrestal Building
Room 8E-089

9:00	Convene Opening Remarks and Administrative Items	Ivan Bennett Chairman
9:30	Trends in Manpower, Federal and Industrial Funding for R&D in Universities	Charles Falk Director Science Resource Studies National Science Foundation
10:30	Energy Research University Programs	James Kane Deputy Director Energy Research
11:15	Nuclear Energy University Programs	Tom Dillon Deputy Assistant Secretary Nuclear Energy
11:45	Fossil Energy University Programs	Bob Roberts Senior Scientific and Technical Advisor Office of Fossil Energy
12:15	Lunch	
1:15	DOE University Procurement Policies and Procedures	Hilary Rauch Director Procurement and Assistance Management
2:00	Status Report on Studies	Colin West Oak Ridge National Laboratory
2:30	Adjourn	

63

University Programs Panel
Energy Research Advisory Board
Agenda

21 March 1983
Forrestal Building
Room 8E-089

9:00	Convene Opening Remarks and Administrative Items	Ivan Bennett Chairman
9:10	Conservation University Programs	Howard Coleman, Principal Deputy Assistant Secretary for Conservation and Renewable Energy
9:35	Preliminary Report on Survey of University Associations, Officials and Scientists	Colin West Oak Ridge National Laboratory
10:05	Break	
10:15	Presentations by Representatives from Universities on DOE Programs, Policies, and Procedures	George Dummer, Director of Sponsored Programs, MIT Robert Marston, President University of Florida T. A. Tombrello, Department of Physics, California Institute of Technology David Menzel, Director Skidaway Institute of Oceanography, University of Georgia Joseph E. Lannutti Associate Vice President Academic Affairs, Florida State University
11:15	Discussion with University Representatives	
12:00	Lunch	
1:00	Renewable Energy University Programs	Robert San Martin, Deputy Assistant Secretary for Renewable Energy
1:30	National Laboratory Programs and Policies Relating to Universities	Herman Postma, Director Oak Ridge National Laboratory Douglas Olesen, Director Pacific Northwest Laboratory
2:30	Discussion of Panel Report	Panel Members
5:00	Adjourn	

University Programs Panel
Energy Research Advisory Board
Agenda

29 April 1983
Forrestal Building
Room 8E-089

9:00	Convene Opening Remarks and Administrative Items	Ivan Bennett Chairman
9:10	National Science Foundation Policies and Programs for University Research and Development	Edward Knapp, Director National Science Foundation
10:30	DOE Defense Research and Development University Programs	Herman Roser Assistant Secretary for Defense Programs
11:00	Break	
11:15	Policies and Procedures Used by Program Directors in Selecting R&D Performers	Richard Kropschot Associate Director for Basic Energy Sciences
12:15	Lunch	
1:30	Status Report on Panel Studies	Colin West Oak Ridge National Laboratory
1:45	Discussion of Draft Report	Panel Members
5:00	Adjourn	

57-279 O - 87 - 52

65

University Programs Panel
Energy Research Advisory Board
Agenda

18 May 1983
Forrestal Building
Room 8E-089

9:00	Convene Opening Remarks and Administrative Items	Ivan Bennett Chairman
9:15	Status Report on Data Collection	Colin West Oak Ridge National Laboratory
9:30	Report on Case Studies	Ann Watts Syracuse University
10:00	Break	
10:15	Discussion of Recommendations from Individual Panel Members	Panel Members
11:15	Discussion of Draft Issues and Recommendations	Panel Members
12:15	Lunch	
1:15	Continue Discussion	Panel Members

66

University Programs Panel
Energy Research Advisory Board
Agenda

23 June 1983
Forrestal Building
Room 4A-110

9:00	Convene Introductory Remarks	Ivan Bennett
	Discussion of Draft Report	Panel Members

ATTACHMENT E

DRAFT DOE POLICY STATEMENT OF DOE-UNIVERSITY RELATIONSHIPS

ATTACHMENT E

DRAFT DOE POLICY STATEMENT OF DOE-UNIVERSITY RELATIONSHIPS

Subject: Basic Policy for DOE-University Relationships

Purpose

This memorandum provides policy guidance with regard to relationships between the Department of Energy and universities and colleges participating in Department-supported research and related activities.

Definition

In this memorandum, *university* is used as a generic term covering all nonprofit institutions of higher education and educational nonprofit organizations that are directly affiliated with such institutions. The term *research* is principally defined as that research necessary to expand the energy technology base and includes both general scientific research and basic applied research and exploratory development.

Background

Universities are unique national resources responsible for conducting long-range research, educating students, and providing technical assistance to external groups through public service and outreach. Universities have traditionally played important roles in major national programs such as national defense, agriculture, health and human services, and the aerospace program and in general science and technology development. University scientists and engineers have also made significant contributions through research to the development of new, more effective energy technologies and through this process have provided the necessary education for new scientists and engineers needed for both current and future energy programs.

University Participation in Department Programs

The Department bases its research support policy on the criterion of excellence, regardless of the location and type of performer. The competitive process provides the highest assurance that the best research will be supported. University participation in Departmental research should not be based on "set asides" or otherwise sheltered funding except in unusual circumstances but rather on identification of those university researchers who are the "best performers," recognizing contributions to the education of new scientists and engineers as one important dimension of performance. It is within this policy context that the Department seeks to encourage and support the involvement of university scientists and students, wherever appropriate, in each research and technology development program. To a significant degree, this support constitutes a necessary national investment in sustaining the quality and quantity of well-trained scientific and engineering personnel who, in the future, will be required to meet the nation's needs.

In pursuing these policies, taking into account the special nature and capabilities of the universities, the Department must follow clear criteria. In particular, principal emphasis should be on engaging universities and university scientists in advanced, long-term research that strengthens the technology base for all energy-related areas and that includes students as active partners and participants. In addi-

tion, it is important that the Department foster close cooperation in research and education between universities and industry and between the national laboratories and universities—viewing all three elements as a coherent system to which each contributes and from which each derives benefits. At the same time, it is obvious that each critical element, whether a university, a national laboratory, or an industrial performer, operates in a distinct and differing environment from the others. Hence, Departmental managers are expected to recognize these differences and apply appropriate management and administrative systems and techniques that are compatible with the distinctive needs and circumstances of each major element.

Policy

To accomplish the above, it is the intent and policy of the Department to

1. involve university scientists in Departmental energy research and development programs with the expectation that they will conduct a significant fraction of the advanced, longer-term technology base research required by individual agency programs;
2. avoid the use of special funding set-asides for university support except in unusual circumstances;
3. solicit and incorporate the advice of university scientists and engineers, either as individuals or through established advisory groups or professional associations, in the planning and execution of energy research and technology development programs;
4. recognize the educational impact and benefits of advanced research by encouraging and providing support for the participation of students in all appropriate Department-sponsored university projects;
5. encourage university researchers to show independence and creativity in their advanced research, including, where appropriate, the preparation and submission of multidisciplinary, cross-programmatic research proposals, subject to periodic peer and program evaluation;
6. encourage interaction and collaboration in energy research among universities and industry, the national laboratories and the Energy Technology Centers, including consideration of and, as appropriate, support for joint research projects;
7. provide increased opportunities for faculty and students in traditionally minority universities, including the Historically Black Colleges and Universities, to participate in Department-sponsored research, both directly and through the national laboratories;
8. expand opportunities for university researchers to use the special and unique facilities and equipment in the multiprogram national laboratories and energy technology centers, whose directors are responsible for ensuring appropriate access to such facilities for university researchers;
9. ensure that the execution and administration of university research grants and contracts are in conformity among all the cognizant field procurement offices; and
10. conduct the Department's overall relationships with the university community in a manner that reflects concern and understanding for the special role of universities in research and education and avoids imposition of burdensome administrative requirements not suited to a university research environment.

Policy Guidelines

The following guidelines are established to ensure that the Department's university programs conform to the spirit of the policies stated above:

1. In addition to responding to competitive solicitations, university scientists should be encouraged to submit unsolicited research proposals to all Departmental programs. Announcements outlining programmatic research interests and needs should be widely distributed, written in a clear and concise form, and require the least burdensome type of response. Notices of Program Interests are particularly appropriate. Efforts should also be made by program staff to review preliminary proposals or other preproposal information from university scientists. Such efforts will enable these researchers to gain a more comprehensive understanding of the

objectives of the Department's energy research and development programs and aid them in focusing their research on the most suitable topics and problems.

2. Department-sponsored research projects should be generally compatible with the interests and capabilities of universities and should normally avoid support for short-term, subprofessional types of work that do not directly or significantly contribute to the university's educational mission.
3. Wherever possible, reasonable continuity of university research projects should be maintained. This requires programmatic and administrative attention to timely award renewals and the use, where appropriate, of multiyear awards to help minimize adverse and burdensome effects on faculty, students, and the institution. Abrupt changes in the funding and monitoring of ongoing university research projects should be avoided. Particular care should be taken to ensure that adequate funding stability is provided to university research projects involving graduate students.
4. Reporting and administrative requirements on university research projects should be held to the minimum consistent with the Department's financial and program management oversight responsibilities.

Responsibilities

1. The responsibilities for implementing the above policies and for strengthening current and developing new university research programs is delegated to the appropriate Program Assistant Secretaries and the Director of Energy Research with overall coordination provided by the Under Secretary.
2. To evaluate the effectiveness of the Department's support of university research, the Under Secretary, with the assistance of the Director of Energy Research and the Program Assistant Secretaries, will prepare for the Secretary an annual report describing the extent and types of university involvement in Departmental programs.
3. The Assistant Secretary for Management and Administration is responsible for ensuring that administrative requirements, including procurement/assistance requirements, on university research projects are applied consistently throughout the Department and at the minimum level necessary to fulfill Departmental financial and award oversight procedures.

*U.S. GOVERNMENT PRINTING OFFICE : 1985 0-421-060/157

DOE/S-0015

The Department of Energy Multiprogram Laboratories

Prepared by the Multiprogram Laboratory Panel

September 1982

A Report of the
Energy Research Advisory Board
to the
United States Department of Energy
Washington, D.C. 20585

Department of Energy
Washington, D.C. 20585

ENERGY RESEARCH ADVISORY BOARD
September 16, 1982

Honorable W. Kenneth Davis
Deputy Secretary of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Ken:

I am pleased to forward the final Report of the Multiprogram Laboratory Panel of the Energy Research Advisory Board. This report, approved unanimously by the ERAB on September 10, 1982, was prepared in response to your request on September 29, 1981, to undertake a comprehensive study that will help shape the future of the Department's multiprogram laboratories.

Among the several findings and recommendations of this report is a greater need for stability and continuity in policy and purpose in managing and funding the Laboratories. This need arises from a decade of major shifts, the result of both Congressional actions and shifts in Administration policies. Obviously such changes are fundamental to our system of government and are not likely to be avoided. Some of the major impacts on the multiprogram national laboratories might have been reduced if there had been a single, stable, top-level office concerned only with the laboratories as long-term assets, physical and personnel. The present situation is in part the result of overfragmentation of the long-term programmatic decision process. A major recommendation aims at establishing such a functional office in the Office of the Under Secretary. In addition, the Board recommends that the Department urge the Office of Management and Budget to support rolling two-year Congressional appropriations for research and development with carry-over funding to stabilize further Department and laboratory planning and program execution.

The Board is in full agreement that the multiprogram laboratories are an impressive research and development asset. The Board recommendations, listed in the Executive Summary, are designed to suggest to the Department means by which the laboratories can be utilized even more effectively.

Sincerely,

Louis H. Roddis, Jr.
Chairman
Energy Research Advisory Board

Enclosure

Department of Energy
Washington, D.C. 20585

ENERGY RESEARCH ADVISORY BOARD

August 31, 1982

Mr. Louis H. Roddis, Chairman
Energy Research Advisory Board
110 Broad Street
Charleston, South Carolina 29401

Dear Lou:

I am pleased to submit the Final Report of the Multiprogram Laboratory Panel to the Energy Research Advisory Board for consideration at its meeting on September 9-10. Since the White House Science Council Federal Laboratory Review Panel has asked ERAB to brief it in mid-September on the results of the laboratory study, action by ERAB at the September 9 meeting would be most timely.

The Final Report completes the Panel's work in connection with the Deputy Secretary of Energy's request to ERAB to provide a comprehensive study to aid the Department in planning for the future of the multiprogram laboratories. There is general agreement among Panel members on the findings and recommendations.

The Panel very much aporeciates the cooperation of the laboratories, operations offices, and Headquarters in this effort. To facilitate ERAB's review, I am sending the report to all Board members by copy of this letter.

Sincerely,

Ivan

Ivan Bennett, Chairman
Multiprogram Laboratory Panel

Enclosure

ENERGY RESEARCH ADVISORY BOARD

Chairman
Louis H. Roddis, Jr.
Charleston, SC

Vice Chairman
Ivan L. Bennett
Professor of Medicine
New York University Medical Center

MEMBERSHIP

Herman R. Branson
President
Lincoln University (Pennsylvania)

Soloman J. Buchsbaum
Executive Vice President
Customer Systems
Bell Laboratories

Melvin Calvin
Professor of Chemistry
University of California
at Berkeley

Dayton Clewell
Senior Vice President (Retired)
Mobil Oil Corporation

Thomas B. Cochran
Senior Staff Scientist
Natural Resources Defense Council

Floyd L. Culler, Jr.
President
Electric Power Research Institute

Martin A. Elliott
Consultant to
Texas Eastern Transmission Corporation

James C. Fletcher
Professor of Technology and
Energy Resources at the
University of Pittsburgh

John S. Foster, Jr.
Vice President for
Science and Technology
TRW, Inc.

Norman Hackerman
President
Rice University

Charles J. Hitch
President Emeritus
University of California at Berkeley

Hans H. Landsberg
Senior Fellow
Resources for the Future

William S. Lee
President and Chief Operating Officer
Duke Power Company

William T. McCormick
President
American Natural Resources Company

David Pimentel
Professor
Department of Entomology and
Section on Ecology and Systematics
Cornell University

Eric H. Reichl
President (Retired)
Conoco Coal Development

Roland W. Schmitt
Senior Vice President
Corporate Research and Development
General Electric Company

John W. Simpson
Consultant to
International Energy Associates, Ltd.

Grant P. Thompson
Senior Associate
The Conservation Foundation

Victoria J. Tschinkel
Secretary
Department of Environmental Regulation

STAFF

Thomas J. Kuehn, Executive Director
Energy Research Advisory Board
Department of Energy

PANEL MEMBERSHIP

Ivan Bennett, Chairman*
Dean and Provost
New York University Medical Center

William Carey
Executive Officer
American Association for The
Advancement of Science

Floyd Culler*
President
Electric Power Research Institute

James C. Fletcher*
William K. Whiteford
Professor of Technology and
Energy Resources
University of Pittsburgh

Charles Hitch*
President Emeritus
University of California

Hans H. Landsberg*
Senior Fellow
Resources for the Future

Henry R. Linden
President
Gas Research Institute

Alan M. Lovelace
Vice President for
Science and Engineering
General Dynamics Corporation

Herman Postma
Director
Oak Ridge National Laboratory

Robert Pry
Executive Vice President for R&D
Gould, Inc.

Roland Schmitt*
Senior Vice President
Corporate Research and Development
General Electric Company

John M. Teem
President
Association of Universities for
Research in Astronomy, Inc.

Louis H. Roddis, Jr.*
Chairman
Energy Research Advisory Board
(ex officio member)

Executive Secretary:
Joseph E. Machurek
Office of Energy Research
Department of Energy

Mary Gant
Science & Technology Affairs Staff
Office of Energy Research
Department of Energy

*ERAB Member

TABLE OF CONTENTS

VOLUME I

Page

Abstract ... xi
I. Executive Summary ... 1
II. Introduction ... 5
III. Overview of the Multiprogram National Laboratory Complex
A. Historical Perspective ... 7
B. The Individual Laboratories ... 8
C. Current Status of the Laboratories ... 9
D. Special Laboratory Roles ... 9
E. External Relationships ... 10
IV. The Appropriate Roles and Missions of the Laboratories vis-à-vis Universities and Industry
A. Assessment of Roles and Missions ... 13
B. Findings and Recommendations ... 14
V. The Scientific and Technological Capabilities of the Laboratories
A. Laboratory Resources ... 17
B. Assessment of Capabilities ... 18
C. Findings and Recommendations ... 19
VI. The Department's Policies and Procedures With Respect to the Laboratories
A. Management Policies and Procedures ... 21
B. Assessment of Policies and Procedures ... 22
C. Findings and Recommendations ... 23
VII. The Effectiveness of the Department's Use of the Laboratories in Meeting Its Energy Objectives
A. Assessment of Effectiveness ... 25
B. Findings and Recommendations ... 26
VIII. Alternative Strategies for Making Best Use of the Laboratories in a Constrained Budgetary Environment
A. Assessment of Strategies ... 27
B. Findings and Recommendations ... 27
IX. Additional Considerations
A. Appropraite Size of the Laboratory Complex ... 29
B. Suitability of Agency Assignments ... 29
C. Effects on Laboratories of Recommendations in the Federal Energy R&D Priorities Report ... 29

Attachment A. Deputy Secretary's Charge ... 31
Attachment B. Capsule Summaries ... 35
Attachment C. Significant Accomplishments Illustrative of Multiprogram National Laboratory Research ... 49

Volume II

Support Studies Prepared by Oak Ridge National Laboratory

I. Summary
II. Report of Statistical Data on the Multiprogram Laboratories
III. Examples of National Laboratory Use in Foreign Countries
IV. Domestic Models for National Laboratory Utilization
V. Relationships of Laboratories with Industry and Universities
VI. Uses of Laboratories for Training Industrial R&D Personnel
VII. Legal Mandates and Constraints on National Laboratories

Volume III

Appendix I. Laboratory Goals and Missions Statements
Appendix II. Laboratory Program Mix
Appendix III. Class Waiver of Government Rights in Inventions Arising from the Use of DOE Facilities by or for Third Party Sponsors
Appendix IV. DOE 4300.2: Research and Development Work Performed for Others
Appendix V. DOE 5000.1: Institutional Planning Process
Appendix VI. Procedure for New Work Assignments at R&D Laboratories
Appendix VII. DOE 5800.1: Research and Development Laboratory Technology Transfer Program

ABSTRACT

The Final Report of the Multiprogram Laboratory Panel of the Energy Research Advisory Board responds to the Department of Energy's request for "a comprehensive study that will help shape the future of the Department's multiprogram laboratories." The Panel assessed, in energy-related areas, the appropriate roles and missions of the laboratories vis-à-vis industry and universities, the scientific and technological capabilities of the laboratories, the Department's policies and procedures with respect to the laboratories and the effectiveness of the Department's use of the laboratories.

The laboratory complex constitutes an impressive national research and development asset. However, the industry and university research establishments often carry out comparable work, usually with differing goals, objectives, and institutional settings. The issue at hand is how to make use of all of these resources for the benefit of the country as a whole.

The Panel recommends the following major roles and missions for the laboratories:

- Perform the Department's "national trust" fundamental research missions in the physical sciences, including high energy and nuclear physics, and the radiobiological sciences including nuclear medicine;
- Sustain scientific staff core capabilities and specialized research facilities for laboratory research purposes and for use by other Federal agencies and the private sector;
- Perform independent scientific and technical assessment or verification studies required by the Department; and
- Perform generic research and development where it is judged to be in the public interest or where for economic or technical reasons industry does not choose to support it.

The Panel finds that organizational efficiencies if implemented by the Department could contribute toward optimal performance of the laboratories. The Panel recommends that a high level official, such as a Deputy Under Secretary, be appointed to serve as Chief Laboratory Executive with authority to help determine and defend the research and development budget, to allocate resources, to decide where work is to be done, and to assess periodically laboratory performance. Rolling two-year appropriations by Congress for research and development are recommended as a stabilizing measure. The Panel also recommends that laboratory directors be given substantially more flexibility to deploy resources and to initiate or adapt programs within broad guidelines provided by the Department.

The Panel recommends the following actions to increase the usefulness of the laboratories and to promote technology transfer to the private sector:

- Establish user groups for all major mission programs and facilities to ensure greater relevance for Department and laboratory efforts.
- Allow the laboratories to do more reimbursable work for others (other Federal agencies, state and local governments, and industry) by relaxing constraints on such work.
- Implement vigorously the recently liberalized patent policy.
- Permit and encourage joint ventures with industry.
- Expand laboratory/university cooperation in the training of scientists and engineers at laboratory facilities.

Finally, the Panel finds that some of the multiprogram laboratories are currently funded at close to minimum levels for maintaining their present capabilities. In the event of further budgetary reductions, some measures, such as narrowing laboratory missions or directing additional work to them in lieu of establishing new laboratories, are suggested for preserving as much as possible of the capabilities of the laboratory complex.

I. EXECUTIVE SUMMARY

In specific terms, the Deputy Secretary of Energy charged the Energy Research Advisory Board with assessing, in energy-related areas, the appropriate roles and missions of the laboratories vis-à-vis industry and universities, the scientific and technological capabilities of the laboratories, the Department's policies and procedures with respect to the laboratories and the effectiveness of the Department's use of the laboratories. The recommendations of this Executive Summary and the body of the Report respond to these specific charges.

In a broader context, the Deputy Secretary requested "... a comprehensive study that will help shape the future of the Department's multiprogram laboratories." In responding to this request the Multiprogram Laboratory Panel found it appropriate, and indeed mandatory, to consider a broader laboratory role in innovation and productivity in the national economic interest. The Panel concluded in this regard that the present management direction and practices respecting the laboratories, developed over time, are not consistent with their long-range future well-being and, further, that these arrangements deny to the Nation the full benefits of this national research and development asset.

A. The appropriate roles and missions of the laboratories vis-à-vis universities and industry (see pp. 13-15).

1. Findings

- The multiprogram national laboratory complex constitutes an impressive national research and development asset. Moreover, it possesses capabilities for the performance of large-scale, long-term, high-risk, multidisciplinary research and development; however, these characteristics in and of themselves do not uniquely define appropriate roles and missions for the national laboratory complex. The industry and university research establishments are capable of and often carry out work comparable to much of that performed by the national laboratories, albeit often with differing goals, objectives, and institutional settings. The issue at hand is how to make the best use of the existing research and development assets of the multiprogram laboratories in the context of the national scientific and technical enterprise.
- Current Administration policy calls for increased reliance upon the private sector for technological advancements but recognizes an appropriate Federal role in supporting long-range, high-risk, potentially high-payoff research and development of national interest beyond that which can be expected from the private sector. The Panel concludes that there exist areas of research and development that require the complementary capabilities of the university, industrial, and laboratory sectors.

2. Recommendations

In energy-related areas, the Panel recommends the following functions as appropriate for performance by the national laboratory complex, subject to university and industry participation as noted.

a. Direct Functions

- Carry out core elements of the Department's traditional "national trust" fundamental research missions in the physical sciences, including high energy and nuclear physics, and the radiobiological sciences, including nuclear medicine; in so doing,
  - perform research utilizing their unique capital intensive research facilities to ensure that the capabilities of the facilities and scientific staff evolve appropriately to meet the needs of university, industrial, and other Federal research communities.
  - exercise stewardship of these facilities and provide associated technical expertise to enable their efficient use by these communities.
- Perform research and development on the health, safety, and environmental externalities incident to promising energy technologies under development (not necessarily limited to those enjoying government funding) whenever high scientific competence or specialized facilities are available at the laboratories or when performance of such work by industry or, where relevant, universities would pose an apparent or actual conflict of interest.

- Perform generic energy research and development where it is judged to be in the public interest or where for economic or technical reasons industry does not choose to support it. Government funding may provide support for either universities, industry, or the national laboratories, consistent with:
  - i) Department utilization of the best available performer for the given task
  - ii) Cooperation with intended users of the technology in determining applications oriented work to be performed in the laboratories
  - iii) Industry access to the facilities and staff of government laboratories for research and development funded privately, or with government funds, under appropriate policy guidance.

b. Support Functions

- As requested, and in conformance with explicit policy guidelines and budgets established by the Department, act as agents for the Department in exercising broad technical management responsibilities for complex packages of multilaboratory and/or subcontracted research and development work.
- In accordance with applicable Department policy, make the special capabilities and expertise of the laboratories available for technical assistance and reimbursable research and development to other Federal agencies; state and local governments; and regional entities, universities, and industry.
- Within their areas of capability and expertise, contribute toward the education and training of scientists and engineers by providing opportunities for this purpose at the laboratories to university faculty and students, industrial professionals, and, in accordance with national policy, foreign nationals.
- Assist the Department in the discharge of its overall resposibilities by:
  - providing technical counsel to the Department on national research and development policies and future directions
  - acting as systems engineers, advisors, and evaluators for the Department in areas where such involvements by others would constitute an apparent or actual conflict of interest
  - providing a fast start-up or multidisciplinary approach not otherwise readily available to meet quickly an urgent or emergency need for research and development, technical expertise or timely and reliable data of a critical nature
  - supporting fulfillment of international agreements.

B. The scientific and technological capabilities of the laboratories (see pp. 17-19).

1. Findings

- Overall, the Panel finds the scientific and technological capabilities of the laboratories impressive, but DOE organizational inefficiencies and funding policies are obstacles to their full realization.
- The Panel is uniformly impressed with the qualities and resourcefulness of laboratory leadership.
- The scientific and technical resources of the laboratories, including their physical facilities, cannot be utilized effectively under prolonged budgetary uncertainty and the pressure of repetitive crash readjustments in program funding.
- Layering and fractionation of managerial and research and development responsibilities in DOE require the laboratories to interact with DOE on an excessive number of horizontal and vertical levels and with heavy reliance on negotiation. The absence of a coordination and resolution officer with full authority at the Headquarters level giving attention and support to the laboratory directors results in inefficient utilization of laboratory scientific and technical capabilities.

2. Recommendations

- Urge the Office of Management and Budget to support rolling two-year appropriations by Congress for research and development with carry over funding to stabilize Department and laboratory planning and program execution.
- Designate a high level official, such as a Deputy Undersecretary, whose sole function is to be the Chief Laboratory Executive with authority to help determine and defend the research and development budget; to allocate resources; to decide where work is to be done; and to assess laboratory scientific, technical, and managerial performance.
- Consistent with the foregoing, modify the roles of the operations offices with respect to the laboratories to focus on management of the contracts with the laboratory operating contractors and to de-emphasize their function as policy and programmatic intermediaries between Headquarters and the laboratories.
- Arrange for the laboratory directors to have substantially more flexibility, within overall budgets and broad program guidelines, to reprogram assign-

ed laboratory resources and to initiate or adapt programs in accordance with research and development opportunities. This reprogramming authority should be no less than 5% or more than 10% subject to the satisfactory completion of the original assigned program activity. If additional Congressional authorization for this reprogramming is needed, the Department should seek it.

C. The Department's policies and procedures with respect to the laboratories. (see pp. 21-23).

1. Findings

- The laboratories have become grossly overburdened with detailed reporting and other paperwork requirements, the utility of which frequently is not apparent and which unnecessarily divert resources from their research and development missions.
- The Department's laboratory Institutional Planning Process is proving itself valuable, both to DOE Headquarters and the laboratories, although care needs to be taken that it produces a workable plan and not a strait jacket.
- The Department's approach toward appraising laboratory performance has been somewhat lacking in systemization, codification, and management follow-up. The Panel is pleased to note that the Department is in the process of rectifying this situation.
- The Department's restrictions on laboratory work for others, particularly industry, are unnecessarily constraining. Among other things, such restrictions frustrate technology transfer efforts.
- The Department's patent policy, particularly in connection with laboratory work for others, has been among the salient barriers to cooperative relationships with industry and to effective technology transfer. The Panel notes with approval that the Department recently has taken steps to liberalize its policy in this area.

2. Recommendations

- Utilize the services of an outside audit contractor familiar with both Government and industry practices to conduct a thorough audit of paperwork requirements in the Headquarters/operations offices/laboratory chain of command.
- Strengthen laboratory Institutional Plans as long-range strategic planning documents, as components of the Department's planning process, and as vehicles for new initiative proposals; de-emphasize their use as constraining budget documents.
- To supplement internal appraisals of laboratory performance, the Department should convene panels from recognized scientific bodies, such as the National Academies of Science and Engineering, to conduct periodic (at intervals not greater than five years) technical audits of laboratory programs in connection with approved institutional plans.
- While maintaining priority status for essential Department missions, allow the laboratories to do more reimbursable work for others (other Federal agencies, state and local governments, and industry) by relaxing constraints on such work.
- Undertake a well-planned education program among Headquarters, operations office, and laboratory staff on the recently liberalized patent policy to ensure that it will be vigorously implemented. In parallel, ensure that the private sector understands the new policy.

D. The effectiveness of the Department's use of the laboratories in meeting its energy objectives (see pp. 25-27).

1. Findings

- The Panel finds that the Department has been conservative in envisioning, not to mention implementing, policies by which the laboratories could be more effectively utilized. This conservatism has resulted in a lesser contribution by the laboratories toward meeting the Department's energy objectives than could otherwise be achieved.
- Contrary to past practices, the expertise of laboratory staff and directorate are not being utilized in establishing Department policy and directions for research and development.
- While laudable in principle, the Department's policy of assigning lead missions to the laboratories has been, with few exceptions, generally ineffective because of excessive fractionation of mission assignments, inadequate delegation of authority to the laboratories, and seeming lack of commitment to the policy by DOE management.
- Under present budgetary constraints a number of the specialized research facilities at the laboratories are being operated far below capacity.
- While use of the laboratories for contributing toward training scientists and engineers to meet the Nation's needs has grown in recent years, this use could increase.
- Research and development program planning does not consider adequately end-user views.
- Institutional and doctrinal barriers toward greater laboratory/industry cooperation continue to inhibit achievement of the Department's energy objectives in general and technology transfer efforts in particular.

2. Recommendations

- Establish a consultant group composed of all the laboratory directors to utilize more effectively laboratory resources in establishing the Department's research and development policy and directions.
- Implement vigorously the assignment of lead missions to the laboratories, defining these in terms of major applied programmatic missions, and provide for significantly greater laboratory discretion in allocation of resources (within overall Headquarters established budgets for the mission area) and in the selection of performers.
- In setting research priorities, give special weight to making optimal productive use of sophisticated equipment and facilities.
- Establish user groups reporting to the Department, similar to the High Energy Physics Advisory Panel and the Nuclear Science Advisory Committee, for all of the Department's major mission programs and facilities. These could be established independently for each program function or under the umbrella of an overall advisory group.
- Continue to support laboratory/university cooperation in the training of scientists and engineers through on-site participation by faculty and students in laboratory programs, term appointments, fellowships, etc.
- Permit and encourage joint ventures in selected projects with industry, including test and pilot demonstration (located at the laboratories or industrial sites) in order to test economic feasibility and to shorten the time lag for technology transfer.
- In areas of special laboratory expertise and capabilities, allow and encourage the laboratories to work more closely with industry by such means as responding to requests for proposals from industry cooperative groups (e.g., American Society of Heating, Refrigeration and Air-Conditioning Engineers; Electric Power Research Institute; and Gas Research Institute) and to work in partnership with industry in meeting technical needs of Federal agencies, as well as working directly for industry in connection with Federal agency requests for proposals.
- Permit each laboratory to use 1% to 2% of its capital and operating budget for independent research and development at the discretion of the laboratory director in order to enrich their research capabilities.
- Through a deliberate review and study by both the Department and the laboratories, identify institutional and doctrinal barriers to effective technology transfer and implement further actions to ameliorate these.

E. Alternative strategies for making best use of the laboratories in a contrained budgetary environment (see p. 27).

1. Findings

- Some of the laboratories are currently being funded at levels close to the minimum consistent with maintaining their present competence and vitality.
- In view of their current broader responsibilities, any further funding reductions that would reduce laboratory staffing below the levels of the mid-1970's would demand that a number of measures, some drastic, be considered to preserve as much as possible the scientific and technical assets of the laboratory complex.

2. Recommendations

Certain measures that would help stabilize the laboratory complex in the event of further budgetary reductions have validity in their own right as contributors toward more effective use of the laboratories. These measures, which have been addressed earlier, relate to the lead mission policy and the freeing of the laboratories to do much more work for others. Additional measures recommended for consideration if necessary include:

- Transferring appropriate DOE-sponsored work now performed by other Federal agencies and directing additional work into the laboratories by assigning to them those new tasks for which new laboratories might otherwise be established.
- Narrowing the missions of the laboratories to correspond to the resources available.
- Closing particular laboratories or merging one or more of them with other DOE laboratories or even with other appropriate institutions outside the Department.

II. INTRODUCTION

This Final Report responds to a request of September 29, 1981, from the Deputy Secretary of Energy (Attachment A) that the Energy Research Advisory Board (the Board) undertake "... a comprehensive study that will help shape the future of the Department's multiprogram laboratories." Specifically, the Deputy Secretary requested the Board's review, appraisal, and recommendations in energy related areas (i.e., other than nuclear weapons related programs) regarding:

- The appropriate roles and missions of the laboratories vis-à-vis industry and universities
- The scientific and technological capabilities of the laboratories
- The Department's policies and procedures with respect to the laboratories
- The effectiveness of the Department's use of the laboratories in meeting its energy objectives.

To perform the requested study, the Board established a Multiprogram Laboratory Panel, composed of both Board and non-Board members (list follows title page). The Panel was charged with reporting its findings to the full Board for review and approval prior to transmittal to the Deputy Secretary.

The Deputy Secretary asked for an interim report giving preliminary recommendations by March 1982 and a final report by September 1982. The Panel's Preliminary Report, issued in March 1982, addressed (a) the appropriate roles and missions of the national laboratory complex vis-à-vis universities and industry and (b) strategies, to be further studied, for making best use of the laboratory complex in a constrained programmatic/budgetary environment. The latter reflected the Panel's consideration of possible means of preserving the laboratory complex as a national asset in light of the Deputy Secretary's expressed concern "... that the scientific and technical strength of the laboratories may be eroded and that their ability to continue to contribute to the Nation's long-range energy needs may be diminished."

In developing its recommendations, the Panel took note of the Administration's proposal of December 17, 1981, to transfer the research and development functions of the Department of Energy (DOE) along with its laboratories to the Department of Commerce, the ongoing overall study of Federal laboratories by the Office of Science and Technology Policy, and the anticipated continuation of budget austerity with regard to Federal support of energy research and development. The Panel additionally consulted in detail with the Department's Headquarters and operations office staffs, the laboratory directors, other Federal agencies, and representatives from industry and universities. Moreover, two or more of the Panel members made full day visits to each of the laboratories, consulting with not only the Director but his principal staff as well.

The Panel found it very important to have a thorough understanding of the origin, development, and history of the laboratories; their changing missions and functions; and the Department's laboratory management processes. Because such background knowledge similarly is important to the reader's understanding of the Panel's findings and recommendations, Section III presents an extensive review of the laboratories in these regards. Readers who are thoroughly conversant with the laboratories need not review this material in detail.

III. OVERVIEW OF THE MULTIPROGRAM NATIONAL LABORATORY COMPLEX

A. Historical Perspective

Historically, 12 DOE laboratories were considerd multiprogram. Currently, three of these laboratories, Hanford Engineering Development Laboratory, Idaho Nuclear Engineering Laboratory, and Savannah River Laboratory, are focused almost exclusively in a single program area. This circumstance is not expected to change in the foreseeable future. In its study, therefore, the Panel decided not to include these laboratores (and, for the same reason, the Solar Energy Research Institute). Accordingly, the nine multiprogram laboratories considered by the Panel are:

- Ames Laboratory
- Argonne National Laboratory
- Brookhaven National Laboratory
- Los Alamos National Laboratory
- Lawrence Berkeley Laboratory
- Lawrence Livermore National Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest Laboratory
- Sandia Laboratories

The national laboratory complex had its origins in the Manhattan Project and was formalized and expanded under the Atomic Energy Commission. The multidisciplinary character of the several laboratories sprang initially from the requirements of the atomic bomb project and related demands in radiation biology and health effects for expertise in virtually all the sciences (e.g., physics, chemistry, biology, engineering, and a wide spectrum of specialities within these disciplines). This feature of the laboratories was accentuated in response to the later inclusion of nuclear power research and development as a major laboratory mission. In this period, there evolved the concept of the laboratories as the guardian of "national trust" missions in physical sciences, including high energy and nuclear physics, and radiobiological sciences, including the lead Federal role in nuclear medicine research. Additionally in the past, the laboratories provided strong technical support and counsel in the Department's research and development policy and planning; in recent years the Department has made little use of this capability.

Under the Energy Research and Development Administration (ERDA) and, subsequently, the Department of Energy, the laboratories were uniquely equipped to contribute significantly to the greatly expanded Federal energy research and development thrusts, including their health, safety, and environmental aspects. Over the years the laboratories also undertook other peripheral, but nonetheless essential, functions. These include managing large research facilities and making them available to university and industry researchers, providing their special capabilities to assist other Federal agencies, and functioning as strong international links in scientific and technological areas. Regardless of their historical development, however, the basic questions today concern what scientific and technical needs of the country could be filled by the laboratories and, of these, which ones could best be filled by them.

By policy decision, the national laboratories were established as federally owned and funded facilities operated and staffed by private contractors. Even today they still represent the largest group, in terms of numbers, staffing, and funding, of government owned contractor operated facilities sponsored by the Federal Government or, indeed, by any nation in the world. The national laboratory complex is further characterized by a diversity of operating contractors, which include individual universities, university consortia, and industrial firms (e.g., Ames Laboratory is operated by Iowa State University; Brookhaven National Laboratory, by Associated Universities, Inc.; and Oak Ridge National Laboratory, by Union Carbide Nuclear Division). This diversity of operating contractors is reflected to a noticeable extent in the character of the individual laboratories. All the laboratories encompassed by this study are characterized by a high degree of multidisciplinarity, extensive research facilities, and an organizational and management structure that facilitates ready assembly of project and program teams as required. However, each laboratory differs in significant respects from the others. Some are highly focused on basic research (e.g., Ames Laboratory), others concentrate on applied research and development (e.g., Oak Ridge National Laboratory), and still others are well staffed and equipped in engineering disciplines (e.g., San-

dia Laboratories). The totality of multidisciplinary expertise, equipment, facilities, and breadth of capability at the national laboratories substantially exceeds that usually found in most university and industry laboratories. Capsule summaries of the individual laboratories are presented in Attachment B and summarized below.

B. The Individual Laboratories

The **Ames Laboratory** conducts basic research in materials and chemical sciences, relying upon existing capabilities for preparing high purity metals, alloys, compounds, and single crystals; and conducts materials related research and development in areas such as nondestructive testing of materials. The laboratory, sharing Iowa State University's campus, enjoys extensive cooperation with the University through year-round faculty appointments, graduate student training, and facility-sharing programs.

The **Argonne National Laboratory** (ANL) provides advanced nuclear technology research and development support to the breeder reactor and other fission reactor programs and maintains a substantial, diversified capability in physical and biological sciences in support of reactor efforts. In basic research, a major effort is materials research and development directed toward providing superior new materials for fission and breeder reactors, fusion devices, and advanced fossil energy systems. The laboratory has developed and operates research facilities such as the High Voltage Electron Microscope and the Intense Pulsed Neutron Source. It is now beginning fabrication of a major, user-oriented facility, the Argonne Tandem-Linear Accelerator System (ATLAS), which will be a national facility for heavy ion research in physics.

The **Brookhaven National Laboratory** (BNL) conceives, develops, constructs, and operates large, complex research facilities (e.g., the National Synchrotron Light Source and the Alternating Gradient Synchrotron) that are used to study fundamental properties of matter and are shared with university and industrial scientific communities. The laboratory conducts basic and applied research in technology base areas, both to support research at other facilities and to discover important new directions for research. Major disciplinary strength is found in the areas of high energy, nuclear, and solid-state physics; chemistry; and biology. Biological and medical programs include studies of the health effects of radiation and of chemical substances involved in the production and use of energy.

The **Lawrence Berkeley Laboratory** (LBL) conceives, develops, constructs, and operates large, complex research facilities, e.g., Bevalac and Super Heavy Ion Linear Accelerator (HILAC), that are shared with university and industrial scientific communities. The laboratory capitalizes on its co-location with the University of California at Berkeley to provide a diverse and flexible assembly of scientific talent for research and advanced development with major research programs in high energy physics, nuclear physics, basic energy sciences, conservation and solar energy, coal research, inertial confinement fusion, geochemistry, computer science, and mathematics.

The primary role of **Lawrence Livermore National Laboratory** (LLNL) is the research, development, and testing of nuclear weapons designs. Expertise developed in this area is also applied to related areas of defense research such as inertial confinement fusion, nonnuclear ordnance, and particle beam technology. LLNL also undertakes research and development technologies of national interest, primarily in the field of energy, where the skill or facilities requirements are unique and synergistic to the weapons effort. As a result, the Laboratory has ongoing programs in magnetic fusion energy, laser isotope separation, biomedical and environmental studies, in-situ coal gasification and oil shale retorting, energy storage systems, transportation energy conservation, and solar energy research and development.

The **Los Alamos National Laboratory's** (LANL) primary mission is the application of science and technology to problems of national security, that is, to the maintenance of a strong defense, the fulfillment of arms control commitments, and the guarantee of a secure energy supply for the future. Major programs include developing nuclear warheads, designing and testing advanced technology devices, and maintaining an innovative weapons design program. In nuclear fission, programs include testing advanced reactor fuel elements, modeling reactor accident results for the Nuclear Regulatory Commission, evaluating biomedical consequences of nuclear energy production, and developing effective nuclear waste disposal methods.

The **Oak Ridge National Laboratory** (ORNL) primarily supports the fission nuclear fuel cycle and magnetic fusion energy development (advanced toroidal devices such as Tokomak and Elmo Bumpy Torus) through scientific research and technology; identifies and solves generic research problems in energy technologies such as materials, separation techniques, chemical processes, and biotechnology; and is the major national source of production of stable and radioactive isotopes. Energy technology development at ORNL also includes other important efforts in residential and commercial energy conservation, renewable energy sources, ecology, biology, and coal conversion and utilization.

The mission of the Pacific Northwest Laboratory (PNL) is the advancement and use of scientific and engineering technology for national security and the nation's multiple energy needs. In accomplishing this mission, high priority is given to safe and reliable nuclear energy and to promising new concepts and technologies for operations at Hanford. Areas of disciplinary strengths and concentration include nuclear waste process development, nuclear fuel development and evaluation, spent-fuel storage and reprocessing, inhalation toxicology, bioelectromagnetics, biology, ecology, atmospheric sciences, corrosion chemistry, biomass research, nondestructive testing and evaluation, materials characterization and research, chemical engineering, health physics technology, and energy economics and policy analyses.

Sandia Laboratories' principal mission is research, development, and engineering of nuclear weapon systems, except for the nuclear explosive. Sandia is also responsible for major energy programs in fossil, solar, fission, and basic energy sciences. Its strength lies in its ability to conduct large, interdisciplinary engineering projects that are both technologically risky and sophisticated. Fundamental understanding and technological development are melded to create an environment conducive to generating new products and processes.

C. Current Status of the Laboratories

Funding and staffing at the multiprogram laboratories increased significantly under ERDA. The high level of staffing reached in the late 1970s later became a matter of concern within the Department of Energy; measures to control laboratory growth, largely successful, were instituted, and employment leveled off at about 41,000. The policies of the present administration, expressed through budgetary retrenchment in areas deemed within the responsibility and capability of industry, caught the laboratories overextended in areas no longer considered appropriate for Federal support. As a consequence, nondefense-related staffing of the laboratory complex at the end of the FY 1982 is lower by about 10% (3500 people) than in FY 1980. Significant staff reductions are possible during FY 1983, depending on the final budget. Staffing problems have not been uniformly distributed among the laboratories. The weapons laboratories were least impacted, although reductions are taking place in some energy research areas, notably in solar energy. The nonweapons laboratories are expected to be at 10% to 20% below peak employment by FY 1983.

D. Special Laboratory Roles

The laboratories commonly are perceived primarily as performers of research and development. However, they currently play additional significant roles that need to be evaluated in considering the future roles and missions of the laboratories. These current additional roles include the following.

Systems Engineers/Technical Consultants. Laboratories play the role of system engineers, advisors, and evaluators for DOE. This is particularly true in those areas where industry has an economic or proprietary interest and, if called upon, might be perceived to have a conflict of interest (e.g., coal conversion processes needing government funding, nuclear safety, etc.). The laboratories help the Department to be an informed buyer in making its commitments outside the laboratories. In this role, too, the laboratories address public health, safety, and environmental issues. Laboratories perform checks and gather data on existing systems and make technical assessments of safety and health-related work. For example, the laboratories have been called upon to prepare drafts of environmental impact assessments and statements. Again, these are areas where industry might be perceived to be less objective about results, were they to produce them. Because choosing areas where data are needed requires a detailed knowledge of rather large, complex engineering entities, the universities have normally been involved only in the basic research end of the spectrum.

Quick Response Service. Laboratories are frequently called upon to provide a fast start-up or apply their multidisciplinary expertise to meet quickly an urgent research and development or technical need. The most recent needs of this kind have been the Three Mile Island accident and the Strategic Petroleum Reserve fire. Many lesser ones involving technical problems occur on a far more frequent basis, and the laboratories are called upon to drop what they are doing and apply their resources to those problems to obtain a rapid and correct answer. The laboratories also have been requested to provide services that, while they have had some technical component to them, did not require innovative technologies or discoveries but rather quick application of knowledgeable manpower. For example, Oak Ridge National Laboratory has provided several technical assessments and analyses in support of residential conservation service legislation.

Stewardship. Laboratories are stewards of many special research facilities that are nationally and internationally unique or at least very rare. The laboratories maintain the continuity of long-term research and make the facilities available to a variety of institutions, usually universities but more recently to industry, even for proprietary research. These research facilities and resources include nuclear reactors, accelerators, atomic particle-scattering facilities, light sources, special equipment, national environmental research parks, and large animal populations.

Agents. For some years laboratories have acted as technical agents for DOE as it adopted a policy of decentralization. Laboratories were given lead missions involving broad technical management responsibilities for implementation planning, organizing, monitoring, and carrying out complex packages of research and development work for the Department, using explicit policy guidelines and budgets established by DOE Headquarters. Much of this included subcontracting a majority of the work to industry and universities.

Production. Some laboratories have unique capabilities to produce items of commerical value, such as radioactive and stable isotopes produced at Oak Ridge National Laboratory with annual sales of $15 million. Industry has not found it profitable to invest its own money for such purposes, but this is an area vital to health and industrial processes and for which there is an international market and competition.

Local and Regional Service. Laboratories, by reason of their geographical locations, have been consultants to state and local governments and have undertaken technical research specific to their geographical regions. Depending upon special circumstances, they provide coal support to other Federal activities in the vicinity and to the other local DOE operations offices in their roles as project managers when they need special technical work performed quickly to provide a basis for making decisions. Examples include assistance to several states by Ames Laboratory in the use of atomic emission and mass spectroscopy techniques for trace metal analysis of air and water; assistance to the city of Berkeley, California, by Lawrence Berkeley Laboratory in the form of technical advice and demonstrations with regard to building energy conservation; and assistance to New York State by Brookhaven National Laboratory in using concrete polymer developed at that laboratory on highway bridge repairs. Additionally, universities have aggregated some of their work around their neighboring DOE laboratories. For example, both Los Alamos National Laboratory and Sandia Laboratories have relationships with the University of New Mexico; Argonne National Laboratory and its associated universities have developed close interaction and mutual support.

Training and Education. Laboratories have frequently been involved in nationwide training and education programs. These include allowing doctoral work to be done at the laboratories, hiring and training postdoctoral students for short periods of time, and actually establishing education branches for use of special facilities at the laboratories as, for example, at Lawrence Livermore and Los Alamos National Laboratories.

Work for Other Federal Agencies. All the laboratories perform some work (10%-20%) for agencies other than DOE, usually because they have special facilities and capabilities or because the law intends it so [e.g., most laboratories perform work funded by the Nuclear Regulatory Commission (NRC), because the law requires DOE to make its laboratories available to NRC]. One example of work for another agency is the development by Sandia Laboratories for the National Oceanic and Atmospheric Administration of acoustic transmission systems for communicating data from ocean bottom instrumentation to surface receivers. Another example is the work for the National Institutes of Health by Lawrence Berkeley Laboratory involving biophysical studies on the effects of heavy ions and clinical trials of the effectiveness of heavy ions as a cancer treatment modality, both employing the Bevalac.

E. External Relationships

The laboratories have a long history of relationships with the university and industry communities through a variety of mechanisms. For some laboratories cooperation with universities has been particularly close because the operating contractor is a university or university consortium. In most laboratories, means are provided for large numbers of university faculty and students (up to 20% of full-time equivalent staff) to work at the laboratories for extended periods. University researchers commonly use unique facilities and equipment at the laboratories. Some laboratory research and development is subcontracted to universities. In FY 1981 this amounted to about $39 million in direct subcontracts plus the not readily calculable value of the universities' free access to unique laboratory research facilities. Laboratory relationships with industry, in general, have been less intimate, but nonetheless significant. Occasionally industry personnel work at the laboratories side by side with laboratory staff on problems of mutual interest. For example, as many as 11 industry personnel at a time from six private firms participated in this manner in Argonne National Laboratory's battery development program. Laboratory research and development subcontracting to industry is common. The best figures the Panel has been able to obtain suggest that the latter approximated $260 million in FY 1981. This work largely consisted of technical and engineering analyses and component and hardware development. In addition, procurements from industry approximated $640 million. In an effort to create closer ties and cooperation, the laboratories and the Industrial Research Institute have established a joint task force to explore and develop means of greater interaction. Close ties are also maintained with the international community through a variety of means, including staff exchanges and the training of foreign na-

tionals at laboratory facilities. Both university and industry scientists serve on outside review committees established by the laboratories to advise them on the quality and performance of their work although use of this process is somewhat spotty. In addition, to comply with the Stevenson-Wydler Technology Innovation Act of 1980, the laboratories have upgraded their technology transfer programs. Most of these external relationships are two-party, in the sense that they are focused on either industry or academia. The most important mechanisms are the following.

User Facilities. A prime purpose of national laboratories is to maintain and make available unique facilities needed by scientists and engineers in many institutions for their research and development work. The emphasis has been on use of facilities by individuals, mainly from universities, but industry use of these facilities is increasing. For example, Brookhaven's National Synchrotron Light Source has been used by 12 major companies, and Sandia's Combustion Research Facility, by seven companies.

Communications Services. Laboratories serve as catalysts and facilitators for scientific communication by (a) arranging a variety of ways for visitors and guests to spend time at a laboratory, often directly involved in laboratory programs, and encouraging laboratory personnel to visit industry and universities; (b) taking the initiative in setting up conferences and workshops on topics of national interest; and (c) helping to build and support communication networks that meet national needs, such as between academic disciplines, between industry and academia, and between policymakers and the research community.

Contracting. Laboratories contract with industry and universities for research and development, provide research and development support for the performers, and serve as a source of technical direction and quality assurance for government programs, a role that for several laboratories has grown considerably since the creation of DOE. On occasion, they contract from industry and utilities for research and development as well as perform work for other nonfederal sponsors (such as state and local governments). For example, Oak Ridge National Laboratory received contracts from 74 nonfederal sponsors in FY 1981 and FY 1982.

Other Partnership Arrangements. Other joint arrangements include (a) direct collaboration whereby researchers work together, most often on an informal personal basis since more formal arrangements can be cumbersome; and (b) complementary assistance whereby the partners help to meet each other's needs in such ways as providing technical assistance quickly, serving on advisory committees, reviewing draft reports and proposals, and working together on committees and panels and in scientific and professional societies.

Built-in Institutional Links. Each of the multiprogram DOE laboratories is, in fact, operated by a nongovernmental institution, a university or university assocation, or a profit or nonprofit firm. Many of these laboratories are also linked to associations of regional universities, and some have developed special links with institutions in their own neighborhood (e.g., Los Alamos and Sandia with the University of New Mexico and Oak Ridge with the Tennessee Valley Authority and the University of Tennessee).

Production Activities. In certain special cases, on behalf of DOE, laboratories are not just developers but also producers of devices and materials (e.g., the radioisotopes produced at Oak Ridge and Los Alamos). These external relationships of laboratories are discussed in considerably more detail in Volume II, Chapter 5.

Use of the Laboratories for Education and Training. National laboratories host a steady stream of scholars, teachers, and students. In many cases, these visits involve temporary appointments at the laboratory. Typically, for example, Oak Ridge, Argonne, and Brookhaven National Laboratories will each have about 1,000 university faculty members and students in residence for all or part of a year, participating in laboratory research programs and exchanging professional insights with laboratory staff. For instance, the Division of Educational Programs at Argonne operates eight programs for visiting faculty, eleven for graduate students, six for undergraduate students, and two for high school students. Guests from universities at Brookhaven during 1981 (including research collaborators) were affiliated with 123 U.S. colleges and universities and 46 foreign universities. Similarly, Lawrence Berkeley Laboratory customarily has on site 500 graduate students doing thesis research. These opportunities for participation and interchange bring many of the best minds in the nation to the national laboratories, and they contribute to building and maintaining a pool of trained manpower for energy research and development.

The roles of DOE laboratories in training industrial research and development personnel are limited. Because education and training are fundamental roles of universities in this country and because industrial firms often provide their own training programs for employees, specific training activities by a laboratory have generally been considered unnecessary and inappropriate. Under a particular set of circumstances, however, laboratories have taken on such responsibilities in the past, and they continue to offer a few short courses and other short-term training programs in specialized areas. These educational and training programs are discussed in more detail in Volume II, Chapters 5 and 6.

IV. THE APPROPRIATE ROLES AND MISSIONS OF THE LABORATORIES VIS-À-VIS UNIVERSITIES AND INDUSTRY

A. Assessment of Roles and Missions

The roles and missions of the laboratories, industry, and universities necessarily must be assessed in the context of the overall Federal energy research and development role as articulated by the Administration. In the Panel's understanding, the Federal policy emphasizes increased reliance on private initiatives for energy technology development and implementation. The Federal policy, however, recognizes an appropriate Federal role in long-range, high-risk, potentially high-payoff energy research and development where profit prospects are remote or where society at large rather than individual private investors would benefit from such research and development.

The comparative major capabilities and limitations of multiprogram laboratories, universities, and industry in the context of the Federal energy research and development role can be described with proximate confidence. The laboratories are well suited for basic and long-range, high-risk research and development, large multidisciplinary efforts, and operation of large capital-intensive research facilities, but they come up short in marketing/commercialization skills. Universities stand out for excellence in basic research and narrowly focused applied research and development, but they are not notably oriented toward market involvement or, with the exception of some sponsored research institutes, for large-scale multidisciplinary efforts. Industry stands out in development, demonstration, and commercialization activities and often displays impressive capabilities for large multidisciplinary efforts, but it tends to focus its basic research and high-risk research and development on corporate goals, unless funded by the Government.

Given these in part complementary and in part overlapping capabilities, the question at issue is how to make best use of the multiprogram national laboratories in the context of the overall energy-related national scientific and technological enterprise.

Each of the laboratories currently is identified with one or a few substantive areas of concentration. These core areas can be expected to remain central to any national energy policy for years to come and are widely recognized as areas of laboratory excellence. In each of these, the laboratories have established strong relations with the users of the research and development. In general, these core areas can be generically identified as follows:

Ames	— Fundamental Energy Science
Argonne	— Nuclear Energy, Fundamental Energy Science
Brookhaven	— Fundamental Energy Science
Lawrence Berkeley	— Fundamental Energy Science
Los Alamos	— Defense
Lawrence Livermore	— Defense
Oak Ridge	— Fundamental Energy Science, Magnetic Fusion, Nuclear Energy (fuel cycle, primarily)
Pacific Northwest	— Waste Management
Sandia	— Defense

As a first approximation, therefore, the role of the laboratories should encompass generically these core areas.

By virtue of the work they perform in their core areas, the laboratories develop expertise applicable to other areas (e.g., the drilling technology developed in the weapons laboratories can be applied in in-situ gasification). The question is, when should work in such other areas be assigned to the laboratories rather than to industry, universities, or nonprofit organizations? One way to resolve this question is to allow the laboratories to compete in these other areas with the other sectors in response to government requests for proposals, basing the competition on expertise and the likelihood that the results will be successfully transferred to the intended users. Short of this, the laboratories generally should be assigned research and development intended ultimately for market application when they have special expertise in the area. More specifically, research and development at the laboratories should be primarily in specific areas of science and technology that respond to:

- The Department's "national trust" missions
- Needs for which the laboratories' scientific or engineering capabilities for making salient contributions are demonstrably superior to those of universities and industry

- Long lead-time innovations requiring new scientific knowledge for which adequate private sector commitments and resources are unavailable
- Path-breaking basic research in support of government missions to which particular laboratory resources are matched
- Environmental and health research where performance by others would be seen as constituting a conflict of interest.

The proper role of DOE in energy research and development is to fund and manage those activities for which industry lacks incentives (e.g., environmental, health, and safety research and development) or for which the economic benefits, although substantial, are either sufficiently uncertain or so far in the future that industry chooses not to risk its own resources. In addition to the question of appropriate topics for Federal funding, there is the question of performance. Who is to perform the energy research and development that DOE sponsors? As a general guideline, DOE should choose the performer that can do the best job. Ability to do the job should be measured according to two variables, technical capability and ability to transfer the results to intended users. Further guidance on the choice of performer for a particular research and development task is given by considering the following three situations: (a) industry or universities have capabilities equal to those of the national laboratories, (b) one segment has the necessary capabilities whereas the others do not, and (c) the necessary capabilities do not exist.

Equal Capabilities. Situations involving equal capabilities need to be judged on a case-by-case basis. If the technology is intended for the market and private firms that have an interest in manufacturing or using the technology have the necessary skills and facilities, they should probably be assigned the work. If, however, the firms with the capability to perform the project are interested in it solely for the purpose of doing business with the Government, no special advantage accrues from assigning the work to them rather than to national laboratories.

Unequal Capabilities. In choices between potential contractors with unequal capabilities, generally, the work should go to the organization having the best capabilities. Building duplicate facilities or skills is, in most instances, a waste of the taxpayer's money. Exceptions are cases involving real or perceived conflicts of interest.

Capabilities Do Not Exist. Where capabilities do not exist, a case-by-case judgement is required. If government funding to create a private sector capability would result in leveraging of significant private funding or tightening the connection to production capability, then industry should be the choice. Otherwise the work should go to either universities or national laboratories, depending on the nature of the research. The creation of new national laboratories within the private sector is inconsistent with Administration policy concerning roles of Government versus those of the private sector. Similar considerations apply to universities. The Government should be alert to opportunities for building facilities and equipment to assist universities in their teaching and research mission.

B. Findings and Recommendations

1. Findings

- The multiprogram national laboratory complex constitutes an impressive national research and development asset. Moreover, it possesses capabilities for the performance of large-scale, long-term, high-risk multidisciplinary research and development; however, these characteristics in and of themselves do not uniquely define appropriate roles and missions for the national laboratory complex. The industry and university research establishments are capable of and often carry out work comparable to much of that performed by the national laboratories, albeit often with differing goals, objectives, and institutional settings. The issue at hand is how to make the best use of the existing research and development assets of the multiprogram laboratories in the context of the national scientific and technical enterprise.
- Current Administration policy calls for increased reliance upon the private sector for technological advancements but recognizes an appropriate Federal role in supporting long-range, high-risk, potentially high-payoff research and development of national interest beyond that which can be expected from the private sector. The Panel concludes that there exist areas of research and development that require the complementary capabilities of the university, industrial, and laboratory sectors.

2. Recommendations

In energy related areas, the Panel recommends the following functions as appropriate for performance by the national laboratory complex, subject to university and industry participation as noted.

Direct Functions

- Carry out core elements of the Department's traditional "national trust" fundamental research missions in the physical sciences, including high energy and nuclear physics, and the radiobiological sciences, including nuclear medicine; in so doing,
  - perform research utilizing their unique capital intensive research facilities to ensure that the

capabilities of the facilities and scientific staff evolve appropriately to meet the needs of university, industrial, and other Federal research communities.

— exercise stewardship of these facilities and provide associated technical expertise to enable their efficient use by these communities.

- Perform research and development on the health, safety, and environmental externalities incident to promising energy technologies under development (not necessarily limited to those enjoying government funding) whenever high scientific competence or specialized facilities are available at the laboratories or when performance of such work by industry or, where relevant, universities would pose an apparent or actual conflict of interest.
- Perform generic energy research and development where it is judged to be in the public interest or where for economic or technical reasons industry does not choose to support it.

Government funding may provide support for either universities, industry, or the national laboratories, consistent with:

i) Department utilization of the best available performertor the given task

ii) Cooperation with intended users of the technology in determining applications oriented work to be performed in the laboratories

iii) Industry access to the facilities and staff of government laboratories for research and development funded privately, or with government funds, under appropriate policy guidance.

Support Functions

- As requested and in conformance with explicit policy guidelines and budgets established by the Department, act as agents for the Department in exercising broad technical management responsibilities for complex packages of multilaboratory and/or sub-contracted research and development work.
- In accordance with applicable Department policy, make the special capabilities and expertise of the laboratories available for technical assistance and reimbursable research and development to other Federal agencies; state and local governments; and regional entities, universities, and industry.
- Within their areas of capability and expertise, contribute toward the education and training of scientists and engineers by providing opportunities for this purpose at the laboratories to university faculty and students, industrial professionals, and, in accordance with national policy, foreign nationals.
- Assist the Department in the discharge of its overall responsibilities by:
  - — providing technical counsel to the Department on national research and development policies and future directions
  - — acting as systems engineers, advisors, and evaluators for the Department in areas where such involvements by others would constitute an apparent or actual conflict of interest
  - — Providing a fast start-up or multidisciplinary approach not otherwise readily available to meet quickly an urgent or emergency need for research and development, technical expertise or timely and reliable data of a critical nature
  - — supporting fulfillment of international agreements.

V. THE SCIENTIFIC AND TECHNOLOGICAL CAPABILITIES OF THE LABORATORIES

A. Laboratory Resources

The multiprogram laboratories represent an accumulation of human and physical capabilities that have been built up over several decades. As a system, they are the largest concentration of such resources in the country and probably the world.

Within a total employment of about 40,000, the multiprogram laboratories employ 8500 full-time equivalent scientists and 5900 full-time equivalent engineers (Table 1). These are supported by an annual budget of close to $3 billion or about 9% of Federal expenditures for research and development. Each of the laboratories contains a broad variety of disciplines spanning the physical sciences and biosciences and engineering and includes a few social sciences.

Table 1 shows that the three weapons laboratories are also the three largest in employment, making up over half of the laboratories' total.

The current book value of the plant and equipment of the nine multiprogram laboratories is about $2.5 billion. The replacement cost of the facilities would be several times that. In addition to being well equipped, the multiprogram laboratories possess a number of unique facilities that attract many users from the private sector. The major facilities are listed in Attachment B. Examples of widely used facilities follow:

Argonne National Laboratory	Intense Pulsed-Neutron Source
Brookhaven National Laboratory	Medical Research Center National Synchrotron Light Source
Lawrence Berkeley Laboratory	National Center for Electron Microscopy 88-inch Cyclotron
Los Alamos National Laboratory	Meson Physics Facility
Oak Ridge National Laboratory	National Center for Small-Angle Scattering Research
Sandia Laboratories	Combustion Research Facility Central (Solar) Receiver Test Facility

Table 1. Number of scientists and engineers employed at the multiprogram laboratories[1] (full-time equivalents)

	Scientists	Engineers
Ames Laboratory	343	46
Argonne National Laboratory	1,035	605
Brookhaven National Laboratory	712	342
Lawrence Berkeley Laboratory	734	304
Lawrence Livermore National Laboratory[2]	1,600	1,105
Los Alamos National Laboratory[2]	1,725	905
Oak Ridge National Laboratory	950	660
Pacific Northwest Laboratory	525	340
Sandia Laboratories[2]	904	1,592
	8,528	5,899

[1]Based on data from the most recent institutional plans or from private communications from the laboratories.
[2]Approximately 50% of these scientists and engineers work in defense programs.

The laboratories are organized to respond quickly to the demands of the sponsoring agency to apply management and multidisciplinary talent to a technical problem. In recent years, there have been increasing tendencies to create multilaboratory programs or task forces to bring the best available talent to bear on a problem. A variety of management skills have been used to propose, design, construct, and operate the major facilities that form part of this complex. The laboratories generally turn to subcontractors in the private sector for detailed design and construction services; Sandia, for example, managed about $320 million of procurement in FY 1981.

The management resources of the laboratories are also utilized in their lead mission roles, tools for decentralizing program execution. The number of lead missions currently assigned to the multiprogram laboratories is 32. These include some major programs such as large component development at Argonne, liquid metal fast breeder reactor physics and safety at Argonne, consolidated (nuclear) fuel reprocessing at Oak Ridge, and photovoltaic engineering development at Sandia. Many minor programs, such as reduced-enrichment fuel for research reactors at Argonne, building ventilation at Lawrence Berkeley, and annual cycle energy system at Oak Ridge, are also included.

B. Assessment of Capabilities

The Deputy Secretary's charge in regard to the scientific and technological capabilities, taken to an extreme, would involve an extensive and in-depth analysis covering such questions as:

- Laboratory capabilities for program execution and project management
- The areas of greatest strength (and weakness) in laboratory functional capabilities (e.g., research vis-à-vis engineering development; among disciplines; or for small tasks versus complex, multiyear projects) as well as identification of any unique capabilities
- A comparison of the research performance and overall research capabilities of the laboratories with those of universities and industrial laboratories doing similar work
- A comparison of laboratory capabilities in project management with those of federally funded research and development centers.

Considering the multiplicity of research and development efforts carried out by the laboratories, it was obviously impossible for the Panel to assess systematically even representative samples of the efforts. Fortuitously, the Office of Energy Research recently completed a systematic evaluation of the Basic Energy Science (BES) program consisting of a sample of 129 projects (randomly selected to represent the balance among disciplines from a list of over 1200 completed projects) whose research results were in each case reviewed by panels of specialists. This study was carefully carried out by 180 reviewers from industry, universities, laboratories, and other affiliations (78% of which were from outside the laboratories) thus permitting reasonably objective comparisons of similar efforts carried out in the laboratories and in universities. The BES projects were selected from a range of disciplines in physical, chemical, biological, and engineering sciences that are representative of much of the research and development capabilities of the laboratories. The statistically analyzed results of this study show that laboratory performance compares very favorably with that of universities.

It must be cautioned that the BES program represents only roughly 5% of the efforts of the laboratories under study, and the projects were all relatively small compared with the sizes of projects represented in many other laboratory efforts. While the conclusions of the BES study are reasonably extended to all supporting research and possibly also to general science and environment categories, extrapolation of conclusions to the larger categories of effort (e.g., nuclear, magnetic fusion, and nonweapons defense activities) or to the somewhat smaller categories of energy technology efforts (solar, fossil, conservation, etc.) may be questioned. The Department may wish to carry outcomparable studies in other areas.

The Panel wishes to point out that it is not the *quality* of the laboratory work that is usually questioned; rather, most critical questioning seems to be directed at the appropriateness of what the laboratories have been doing. For example, Dr. Arthur Bueche's testimony for Congressional Committee hearings on "DOE national laboratory relationships with industry and the university community" and his answers to supplemental questions asked by the Committee concerned primarily the balance of work assignments among performers and the standards of utility by which energy research and development results should be judged. Thus, it may be that issues of mission appropriateness and concerns about a perceived overdiversification of the laboratories in recent years may have raised implicit questions about whether the laboratories' output in some areas, while technically sound, has been ill-conceived or poorly managed.

This observation, together with discussions with the Department's Headquarters and operations office staffs, significantly supplemented by detailed discussions at each of the laboratories with the Directors and their senior staff, led the Panel to question whether the existing institutional arrangements respecting the Depart-

ment's organization and management of the laboratories may in themselves be the most significant impediment to optimal utilization of the scientific and technological capabilities of the laboratories. One of the indicators of such an impediment is that the laboratory directors have rather little control over the research and development activities of their own laboratories. The totality of each laboratory's program is primarily the result of individual negotiations between Headquarters and the laboratories at individual staff levels rather than at management levels. By the same token, the Department's management has relatively little control over laboratory activities except through gross budget actions at highly aggregated program levels.

The Panel finds the Department's management of the laboratories in practice is highly disaggregated, a condition further exacerbated by layering and fractionation of research and development responsibilities. Prolonged budgetary and appropriations uncertainty and the pressure of repetitive crash readjustments in program priorities create an environment in which it would be easy for the laboratory to lose its sense of basic mission and its ability to effectively transfer technology, and thus to enter into fields not appropriate for Federal support.

The Panel is impressed by laboratory accomplishments, which are summarized in Attachment C. The Panel further finds, however, that full realization of the laboratories' capabilities requires new institutional arrangements as delineated below.

C. Findings and Recommendations

1. Findings

- Overall, the Panel finds the scientific and technological capabilities of the laboratories impressive, but DOE organizational inefficiencies and funding policies are obstacles to their full realization.
- The Panel is uniformly impressed with the qualities and resourcefulness of laboratory leadership.
- The scientific and technical resources of the laboratories, including their physical facilities, cannot be utilized effectively under prolonged budgetary uncertainty and the pressure of repetitive crash readjustments in program funding.
- Layering and fractionation of managerial and research and development responsibilities in DOE require the laboratories to interact with DOE on an excessive number of horizontal and vertical levels and with heavy reliance on negotiation. The absence of a coordination and resolution officer with full authority at the Headquarters level giving attention and support to the laboratory directors results in inefficient utilization of laboratory scientific and technical capabilities.

2. Recommendations

- Urge the Office of Management and Budget to support rolling two-year appropriations by Congress for research and development with carry over funding to stabilize Department and laboratory planning and program execution.
- Designate a high level official, such as a Deputy Undersecretary, whose sole function is to be the Chief Laboratory Executive with authority to help determine and defend the research and development budget; to allocate the resources; to decide where work is to be done; and to assess laboratory scientific, technical, and managerial performance.
- Consistent with the foregoing, modify the roles of the operations offices with respect to the laboratories to focus on management of the contracts with the laboratory operating contractors and to de-emphasize their function as policy and programmatic intermediaries between Headquarters and the laboratories.
- Arrange for the laboratory directors to have substantially more flexibility, within overall budgets and broad program guidelines, to reprogram assigned laboratory resources and to initiate or adapt programs in accordance with research and development opportunities. This reprogramming authority should be no less than 5% or more than 10% subject to the satisfactory completion of the original assigned program acitivity. If additional Congressional authorization for this reprogramming is needed, the Department should seek it.

VI. THE DEPARTMENT'S POLICIES AND PROCEDURES WITH RESPECT TO THE LABORATORIES

Under U.S. laws and the laboratories' operating contracts, the potential scope of the laboratories is quite broad, encompassing health and safety research and all areas of nuclear and nonnuclear energy and environmental research and development. DOE policies, however, have set limits on what is considered as appropriate work for the laboratories.

For purposes of contract administration, the DOE field operations offices oversee the laboratories. Thus, the Chicago Operations Office is contract administrator for Ames Laboratory, Argonne National Laboratory, and Brookhaven National Laboratory; Albuquerque Operations Office, for Los Alamos National Laboratory and Sandia Laboratories; Oak Ridge Operations Office, for Oak Ridge National Laboratory; San Francisco Operations Office, for Lawrence Berkeley Laboratory and Lawrence Livermore National Laboratory; and Richland Operations Office, for Pacific Northwest Laboratory.

For purposes of programmatic and institutional management, the laboratories report to the Director of Energy Research or to the program Assistant Secretary who funds the major share of the laboratory work. Thus, the Director of Energy Research is the "cognizant secretarial officer" for the Ames, Argonne, Brookhaven, Oak Ridge, and Lawrence Berkeley laboratories; the Assistant Secretary for Defense Programs, for the Los Alamos, Lawrence Livermore, and Sandia laboratories; and the Assistant Secretary for Nuclear Energy, for the Pacific Northwest Laboratory.

A. Management Policies and Procedures

The Institutional Planning Process. To manage this unique set of multiprogram laboratories, the Department employs several management processes. The basic strategic planning vehicle is the Institutional Plan. This is a long-range planning document through which the Director of Energy Research or the Assistant Secretaries for Defense Programs and Nuclear Energy, the other program Assistant Secretaries sponsoring work, the responsible operations office, and the laboratories reach agreement on the general types and levels of activity to be conducted at each laboratory through a five-year planning period. The plan is updated annually and is approved by the appropriate secretarial officer and reviewed by the Under Secretary. The approved plan provides guidance to the laboratory for long-range planning and budget preparation and for site development plans. In addition, it serves as the baseline for placement of work at the laboratory.

Another of the Department's management processes is the periodic appraisal of laboratory performance, both technical and administrative. The Department also makes an annual assessment of requirements for maintaining the laboratory physical plant and endeavors, through the budget process, to accommodate identified needs.

The New Work Assignment Procedure. Supplementing the Institutional Plan process is a new work assignment procedure for considering placement of types or levels of work at the laboratories not contemplated at the time of preparation of the Institutional Plan. Such requests are approved by an official at the assistant secretary level and/or the responsible operations office after evaluation of the suitability of placing the work at a laboratory as opposed to universities or industry and the suitability of the particular laboratory for conducting the work. It is DOE policy to give preference to the private sector in the assignment of work it is qualified to perform. However, because DOE contracting procedures are cumbersome, new work is sometimes awarded to a laboratory as a matter of contractual convenience.

The Panel notes in this regard that neither the Institutional Plan process nor the new work assignment procedure provides a means of assessing the suitability vis-à-vis university and industry capabilities of ongoing work at the laboratories that was initiated prior to the adoption of these management processes.

Policies on Work for Others. The laboratories are permitted, sometimes encouraged, and in certain cases (e.g., Nuclear Regulatory Commission) required to do work for other government agencies. Interagency agreements are set up between DOE and the agency requesting the work.

DOE policies on work for other Federal agencies are given in DOE Order 4300.2, which specifies the follow-

ing restrictions on non-DOE work: (1) it must be determined that private facilities and laboratories are not available to perform the work on a convenient basis and at a reasonable cost; (2) the non-DOE work will not interfere with DOE program activities; and (3) the work must be consistent with DOE's basic responsibilities.

The laboratories are also cautioned not to respond to requests for proposals open to the private sector.

Although other agencies have the statutory authority to request work from DOE, some agencies' policies may actually constrain the laboratories from receiving funds. For example, the *National Science Foundation Grant Policy Manual* (201.1d) specifies that in

> carrying out its statutory purposes, NSF is expressly authorized by its own statutory authority to support research performed by other Federal agencies. However, it presently is Foundation policy not to encourage research proposals from other Federal agencies except in pursuit of specific NSF objectives.

Policies on Technology Transfer. DOE's technology transfer policy implementing the Stevenson-Wydler Technology Innovation Act of 1980 is established in DOE Order 5800.1, "Research and Development Laboratory Technology Transfer Program," issued from Headquarters on March 25, 1982. This order requires the laboratories to conduct technology transfer activities including:

> a) assessement of R&D projects for applicability to the needs of the private sector and state and local governments; (b) application and/or adaption of research or technology into processes, products, and services for use by private sector and state and local governments; (c) technical assistance to the private sector and state and local governments in adapting federally developed technology for use; (d) cooperation with technology transfer brokers to move technology from the laboratories to the private sector and state and local governments; and (e) licensing of DOE-owned patent technology for commercial use.

Each laboratory is required to formulate an annual five-year technology transfer program plan and make an annual technology transfer program report.

It is too early to tell whether the Stevenson-Wydler Act will significantly increase technology transfer between the national laboratories and other sectors. At a minimum, the act requires the Government and its laboratories to put a high priority on technology transfer activities.

B. Assessment of Policies and Procedures

It is not an overstatement that the Department's approach to the laboratories can be characterized as micromanagerial in administrative and procedural matters and quite conservative in its policy constraints on the permitted scope of laboratory activities.

In the former area, the Panel recognizes that there are certain fundamental Federal requirements that must be accommodated and that certain of these derive from the Office of Management and Budget and the Congress. Nevertheless, the Panel finds it disturbing that Argonne National Laboratory, for example, is required to be responsive to 137 different DOE orders and policy issuances, entailing dedication of substantial manpower and funding for compliance, reports, and audits. Equally disturbing is the fact that Argonne receives its funding through 129 separate accounts which are noninterchangeable and require separate controls.

Micromanagement to this degree deprives the laboratory of virtually all flexibility for better management of its resources. Moreover, it results in a significant diversion of laboratory resources from research and development missions. In substance, it deprives the Department of the very benefits and advantages that the government owned contractor operated mode of operation is designed to provide.

Policy constraints upon the laboratories in general are less onerous but nonetheless counterproductive. These constraints lie primarily in the area of laboratory relationships with the private sector and thus adversely affect technology transfer. For example, Departmental policies either preclude or overly limit laboratory work for others, private consulting by laboratory employees, and laboratory responsiveness in appropriate circumstances to government sponsored requests for proposals. Undue restrictions on laboratory work for others, in particular, are counter productive to national technological interests. The scientific and technological capabilities of the laboratories, developed to a high degree of sophistication at public expense over several decades, can contribute significantly beyond the primary laboratory mission responsibilities to other critical areas of national needs supportive of increased innovation, productivity, and international competitiveness. Within reasonable limits, greater accessibility by others to the laboratories for such additional purposes would represent prudent use of this important component of the national technological enterprise.

In certain areas, it must be said in fairness the Department has made important strides. For example, with

respect to appraisal of laboratory performance, which has been somewhat loosely implemented in recent years, the ongoing effort to develop a Departmentwide systemized and codified appraisal procedure with appropriate management follow-up, when completed and implemented, should result in benefits to both the Department and the laboratories. Also, the recently issued class waiver of patent rights in the case of fully cost reimbursed private use of laboratory facilities is a significant advance, assuming it is vigorously pursued at the operations office level. Moreover, the recent DOE Order on technology transfer at least establishes this function as a formal part of the Department and laboratory mission, albeit no dedicated funding appears to be forthcoming as will be necessary if such a function is to become fully operational. The implementation and maturation over the past few years of the laboratory institutional planning process also has been a beneficial initiative. It offers some degree of desirable long-range research and development program planning at the laboratories, although the Panel notes that the tendency to employ the Institutional Plans as constraining budget documents rather than strategic planning vehicles needs to be resisted.

C. Findings and Recommendations

1. Findings

- The laboratories have become grossly overburdened with detailed reporting and other paperwork requirements, the utility of which frequently is not apparent and which unnecessarily divert resources from their research and development missions.
- The Department's laboratory Institutional Planning Process is proving itself valuable, both to DOE Headquarters and the laboratories, although care needs to be taken that it produces a workable plan and not a strait jacket.
- The Department's approach toward appraising laboratory performance has been somewhat lacking in systemization, codification, and management follow-up. The Panel is pleased to note that the Department is in the process of rectifying this situation.
- The Department's restrictions on laboratory work for others, particularly industry, are unnecessarily constraining. Among other things, such restrictions frustrate technology transfer efforts.
- The Department's patent policy, particularly in connection with laboratory work for others, has been among the salient barriers to cooperative relationships with industry and to effective technology transfer. The Panel notes with approval that the Department recently has taken steps to liberalize its policy in this area.

2. Recommendations

- Utilize the services of an outside audit contractor familiar with both Government and industry practices to conduct a thorough audit of paperwork requirements in the Headquarters/operations offices/laboratory chain of command.
- Strengthen laboratory Institutional Plans as long-range strategic planning documents, as components of the Department's planning process, and as vehicles for new initiative proposals; de-emphasize their use as constraining budget documents.
- To supplement internal appraisals of laboratory performance, the Department should convene panels from recognized scientific bodies, such as the National Academies of Science and Engineering, to conduct periodic (at intervals not greater than five years) technical audits of laboratory programs in connection with approved institutional plans.
- While maintaining priority status for essential Department missions, allow the laboratories to do more reimbursable work for others (other Federal agencies, state and local governments, and industry) be relaxing constraints on such work.
- Undertake a well-planned education program among Headquarters, operations office, and laboratory staff on the recently liberalized patent policy to ensure that it will be vigorously implemented. In parallel, ensure that the private sector understands the new policy.

57-279 O - 87 - 53

VII. THE EFFECTIVENESS OF THE DEPARTMENT'S USE OF THE LABORATORIES IN MEETING ITS ENERGY OBJECTIVES

The Department's effectiveness in making use of its laboratories is strongly conditioned by the roles and missions perceived for the laboratories, the organization and management arrangements for fully realizing the scientific and technological capabilities of the laboratories, and the Department's policies and procedures with respect to the laboratories.

A. Assessment of Effectiveness

In some respects, it appears the Department has been rather conservative in utilizing the laboratories' capabilities. For example, although the laboratories constitute an exceptional reserve of scientific and technical knowledge and expertise, in recent years the Department has made little or no use of their capability in Departmental research and development policy and planning. Participation of the laboratories in a consultative capacity in these respects would add an invaluable knowledge dimension to the Department's resources for these purposes.

Through overmanagement and underutilization, the Department has deprived itself and the nation of the best that the laboratories have to offer. In principle the Department adopted the laboratory lead mission concept and the concomitant policy of decentralization; in practice it prejudiced the concept through excessive fractionation of programs and vitiated the policy through inadequate delegation of program execution authority to the laboratories.

Whereas the Department made credible and often successful efforts to create important, highly capital intensive research facilities of national and even international significance, it chooses or is required to fund their operation at levels far lower than those commensurate with their capabilities. In FY 1982, for example, the utilization factor for high energy physics machines ranges from 40% to 45%.

The Department (and the Administration) recognizes the appropriate Federal role in and adequately supports long-range, high-risk potentially high-payoff research and development; however, it limits or precludes as a matter of policy the kinds of close relationships between the laboratories and industry that are necessary if the benefits of such research and development are to be practically realized. Thus, Departmental and national energy research and development objectives would be advanced if policy and procedural avenues were developed by which the laboratories could engage in joint ventures with industry involving test and pilot demonstrations. Similarly, permitting the laboratories to engage with industry in jointly or cooperatively responding to Federal agency technical requests for proposals would better ensure that Federal technical needs benefit from application of the broadest possible spectrum of national scientific and technical expertise. It is recognized that laboratories must participate fairly in vying with the private sector for government work and, therefore, that costing of laboratory work for these purposes must be calculated as nearly as possible on the same bases as is done in industry.

The Department also recognizes the role the laboratories can play in the education and training of scientists and engineers, but it does not exploit this capability to the full extent possible.

In the last analysis, effective use of the laboratories in technology areas is reflected most accurately by the success or lack thereof in the application of the results of laboratory research and development in the marketplace. Issuance of the DOE Order on technology transfer is a significant, but not sufficient, step in the right direction. A major management commitment, backed up by adequate resources, is required. Effective technology transfer is extremely difficult to achieve under the best circumstances. Even if the laboratories were exceptionally well attuned to this function (and they are not), extraordinary efforts will still be necessary to achieve even modest success. Complicating the problem is the fact that the multiprogram laboratories, along with other government laboratories, are constrained by traditional governmental policies and attitudes that inhibit effective technology transfer. Often government laboratories are not permitted to pursue research and development sufficiently far to establish reasonable evidence of technical and economic feasibility and thus to create private interest. Even if they are, industry often has great difficulty in obtaining the patent protection needed to justify its required further development and commercialization in-

vestment, a consideration that strongly inhibits effective technology transfer. The traditional arms-length relationship between government and industry is intrinsically an obstacle to effective technology transfer.

The Department must do much more to seek out and implement measures that will materially facilitate the technology transfer process.

B. Findings and Recommendations

1. Findings

- The Panel finds that the Department has been conservative in envisioning, not to mention implementing, policies by which the laboratories could be more effectively utilized. This has resulted in a lesser contribution by the laboratories toward meeting the Department's energy objectives than could otherwise be achieved.
- Contrary to past practices, the expertise of laboratory staff and directorate are not being utilized in establishing Department policy and directions for research and development.
- While laudable in principle, the Department's policy of assigning lead missions to the laboratories, has been, with few exceptions generally ineffective because of excessive fractionation of mission assignments, inadequate delegation of authority to the laboratories, and seeming lack of commitment to the policy by DOE management.
- Under present budgetary constraints a number of the specialized research facilities at the laboratories are being operated far below capacity.
- While use of the laboratories for contributing toward training scientists and engineers to meet the Nation's needs has grown in recent years, their use could increase.
- Research and development program planning does not consider adequately end-user views.
- Institutional and doctrinal barriers toward greater laboratory/industry cooperation continue to inhibit achievement of the Department's energy objectives in general and technology transfer efforts in particular.

2. Recommendations

- Establish a consultant group composed of all the laboratory directors to utilize more effectively laboratory resources in establishing the Department's research and development policy and directions.
- Implement vigorously the assignment of lead missions to the laboratories, defining these in terms of major applied programmatic missions, and provide for significantly greater laboratory discretion in allocation of resources (within overall Headquarters established budgets for the mission area) and in the selection of performers.
- In setting research priorities, give special weight to making optimal productive use of sophisticated equipment and facilities.
- Establish user groups reporting to the Department, similar to the High Energy Physics Advisory Panel and the Nuclear Science Advisory Committee, for all of the Department's major mission programs and facilities. These could be established independently for each program function or under the umbrella of an overall advisory group.
- Continue to support laboratory-university cooperation in the training of scientists and engineers through on-site participation by faculty and student in laboratory programs, term appointments, fellowships, etc.
- Permit and encourage joint ventures in selected projects with industry, including test and pilot demonstration (located at the laboratories or industrial sites) in order to test economic and to shorten the time lag for technology
- In areas of special laboratory exper capabilities, allow and encourage the labo to work more closely with industry by such as responding to requests for proposals fr dustry cooperative groups (e.g., American Societ of Heating, Refrigeration and Air-Conditioning Engineers; Electric Power Research Institute; and Gas Research Institute) and to work in partnership with industry in meeting technical needs of Federal agencies, as well as working directly for industry in connection with Federal agency requests for proposals.
- Permit each laboratory to use 1% to 2% of its capital and operating budget for independent research and development at the discretion of the laboratory director in order to enrich their research capabilities.
- Through a deliberate review and study by both the Department and the laboratories, identify institutional and doctrinal barriers to effective technology transfer and implement further actions to ameliorate these.

VIII. ALTERNATIVE STRATEGIES FOR MAKING BEST USE OF THE LABORATORIES IN A CONSTRAINED BUDGETARY ENVIRONMENT

A. Asssessment of Strategies

In its March 1982 Preliminary Report, the Panel identified strategies, to be further studied, for making best use of the laboratories in a constrained budgetary environment. In the course of its deliberations, the Panel concluded that two of these, the lead mission policy and freeing the laboratories to do much more work for others, had validity in their own right as contributors to more effective use of the laboratories. These have been discussed earlier. The other strategies envision preferential assignment to the laboratories of new research tasks in lieu of establishing new laboratories for these tasks, transfer to the laboratories of work presently franchised to other agencies, and shutting down or merging laboratories.

The Panel can see no justification currently or in the long run for the Department to establish new laboratories. The other two strategies present some benefits but also substantial risks.

Transferring work currently franchised to other agencies offers benefits in terms of more direct control over mission-supporting research, avoidance of bureaucratic interagency problems, and increased work volume to justify adequate staffing. Risks arise from vested laboratory interests in gaining new work at the expense of siting it in a better environment; from disruption of other agency programs; from possibly higher net costs compared with franchising; and from favoring the laboratories versus employing a highest- and best-use approach to the placement of Federal research work within the larger governmental system.

The benefits of shutting down or merging laboratories are mainly financial, with savings in operating expenses and overhead. The risks are various: irreversibility of decisions to terminate or consolidate; political controversy; adverse morale; possible undeserved termination of certain lines of research; negative impact on university and other present users of unique facilities; and consequences of accommodating to a forcing strategy for budgetary reasons at the expense of long-term expectations for a functioning and diversified laboratory system.

These latter strategies are viewed as drastic and to be considered only as a last resort.

B. Findings and Recommendations

1. Findings

- Some of the laboratories are currently being funded at levels close to the minimum consistent with maintaining their present competence and vitality.
- In view of their current broader responsibilities, any further funding reductions that would reduce laboratory staffing below the levels of the mid-1970's would demand that a number of measures, some drastic, be considered to preserve as much as possible the scientific and technical assets of the laboratory complex.

2. Recommendations

Certain measures that would help stabilize the laboratory complex in the event of further budgetary reductions have validity in their own right as contributors toward more effective use of the laboratories. These measures, which have been addressed earlier, relate to the lead mission policy and the freeing of the laboratories to do much more work for others. Additional measures recommended for consideration if necessary include:

- Transferring appropriate DOE-sponsored work now performed by other Federal agencies and directing additional work into the laboratories by assigning to them those new tasks for which new laboratories might otherwise be established.
- Narrowing the missions of the laboratories to correspond to the resources available.
- Closing particular laboratories or merging one or more of them with other DOE laboratories or even with other appropriate institutions outside the Department.

IX. ADDITIONAL CONSIDERATIONS

The Panel's Preliminary Report identified a number of issues to be addressed in the Final Report, most of which are covered in the Findings and Recommendations. This Section discusses those remaining issues not otherwise addressed in this Report.

A. Appropriate Size of the Laboratory Complex

As the Department's mission changes, it is reasonable to ask how large the laboratory complex should be and whether spending half of the entire DOE budget for research and development through the laboratories is still appropriate.

In FY 1981, about 51% of the Department's research and development budget went to the multiprogram laboratories, whereas only 33% went to industry and universities. On the face of it, the heavy reliance of DOE on its internal laboratories appears to be an anomaly when compared with the degree of internal spending of other Federal agencies. For example, the National Institutes of Health spend more than 90% of their budget externally. The anomaly is, however, more apparent than real. The reasons for the perceived difference can be found in the laboratories' involvement in the weapons programs and in the use of the multiprogram laboratories as conduits for DOE funding of industry and universities.

Over 42% of the multiprogram laboratories' funding in FY 1981 was for nuclear weapons, an area that seems inappropriate for industry and universities. If consideration is limited to DOE's energy research and development work, the multiprogram laboratories received approxi-mately 28% of DOE's budget, whereas industry and universities received 44%. But the multiprogram laboratories' share was actually less than 28% because of pass-through funds.

About 39% of the multiprogram laboratories' total operating budgets in FY 1981 was used for subcontracts and external procurement; most of this money went to industry and universities. Thus, the laboratories' in-house energy research and development probably amounts to no more than 20% of DOE's energy research and development budget. Considering the capabilities of the multiprogram laboratories for performing the long-term, high-risk energy R&D appropriate for Federal funding, it would appear that DOE has not made excessive use of its laboratories. With the trend to more defense spending and to fewer technology demonstrations, it is likely, and reasonable, that a larger percentage of the DOE budget will go to its multiprogram laboratories in the future.

B. Suitability of Agency Work Assignments to the Laboratories, Universities, and Industry

The Agency's laboratory Institutional Planning Process and New Work Assignment procedures are designed in part to control research and development activities assigned to the laboratories vis-à-vis universities and industry in accordance with prescribed criteria. The New Work Assignment procedure appears to accomplish this purpose for ad hoc proposals arising in the course of time. The Institutional Planning Process, however, appears to address this issue only at the margin (i.e., with respect to new work considered at the time the annual Institutional Plans are being developed). It therefore appears that there is no mechanism or process by which work ongoing at the laboratories over long periods of time (predating the foregoing processes and procedures) is reviewed for suitability for universities and industry in light of current circumstances.

Individual assignments to the laboratories are accomplished by a Work Proposal and Authorization System or another comparable mechanism. Review of these documents would provide a means of assessing current suitability of work assignments to the laboratories and should be done.

C. Effects on the Laboratories If the Board's Recommendations Detailed in the Federal Energy R&D Priorities Report Were to Be Implemented

The Panel's original intention to examine this matter was overtaken by programmatic and budgetary events; hence, it was determined such an analysis would not be useful.

ATTACHMENT A

DEPUTY SECRETARY'S CHARGE

THE SECRETARY OF ENERGY
WASHINGTON, D.C. 20585

Mr. Louis H. Roddis, Jr.
Chairman
Energy Research Advisory Board
110 Broad Street
Charleston, South Carolina 29401

Dear Mr. Roddis:

The multiprogram laboratories of the Department of Energy are an important national resource and play a key role in accomplishing the Department's missions. The Department is presently committed to focus its efforts on long-term, high-risk energy research and development and must adjust to an increasingly austere budget. Under these circumstances, I am concerned that the scientific and technical strength of the laboratories may be eroded and that their ability to continue to contribute to the Nation's long-range energy needs may be diminished.

Although the Energy Research Advisory Board is addressing the overall Federal role in energy R&D in your study of R&D priorities, the specific roles and missions of the multiprogram laboratories within this framework have not been examined. Therefore, I would appreciate the Board undertaking a comprehensive study that will help shape the future of the Department's multiprogram laboratories. I am particularly interested in your review, appraisal and recommendations regarding the scientific and technological capabilities of the laboratories, the appropriate roles and missions of the laboratories vis-a-vis industry and the universities, the Department's policies and procedures with respect to the laboratories, and the effectiveness of the Department's use of the laboratories in meeting our energy objectives. I fully expect additional questions to arise related to the laboratories and would appreciate interim reports as your study progresses, with one by March 1, 1982, giving preliminary recommendations.

A final report should be completed by September 1982. I realize that this is a major undertaking in addition to the Board's current efforts, but request that you give it a high priority. You can be assured of the full cooperation and assistance of the Department.

By copy of this letter, I am requesting the Director of the Office of Energy Research, the Assistant Secretaries, Operations Office Managers and multiprogram laboratory Directors to give you their fullest cooperation and support. The Board's efforts should also be coordinated with the Director of the Office

of Energy Research who will provide the necessary resources for the study and will be conducting additional related reviews at my request.

Sincerely,

W. Kenneth Davis
Deputy Secretary

cc:
Director, Office of Energy Research
Assistant Secretaries
Managers, DOE Operations Offices
Directors: Ames Laboratory
Argonne National Laboratory
Brookhaven National Laboratory
Hanford Engineering Development Laboratory
Idaho National Engineering Laboratory
Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Scientific Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory
Sandia National Laboratories
Savannah River Laboratory

ATTACHMENT B

CAPSULE SUMMARIES OF THE DOE MULTIPROGRAM LABORATORIES

Ames Laboratory
Argonne National Laboratory
Brookhaven National Laboratory
Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory
Sandia Laboratories

AMES LABORATORY
Ames, Iowa

The Ames Laboratory conducts basic research in materials and chemical sciences relying upon existing capabilities for preparing high purity metals, alloys, compounds and single crystals, and conducts materials related research and development in areas such as nondestructive testing of materials. Smaller but unique and vigorous capabilities are maintained in high energy physics, nuclear physics, applied mathematics, coal preparation science, and solar technology. The laboratory enjoys extensive cooperations with Iowa State University through year-round faculty appointment, graduate student training, and facilities sharing programs. An effective summer research participation program for undergraduate students and faculty members (primarily from non-local institutions) is maintained by the laboratory to the mutual benefits of it, the participants, and their institutions. The Ames Laboratory actively disseminates the results of its work throughout the scientific and technological communities by the distribution of technical publications, the giving of invited presentations on technologically important topics, the consulting activities of laboratory staff members, the conduct of cooperative projects with industrial and other governmental concerns, and participation in the Federal Laboratory Consortium.

Statistics:

	FY 1982 (Estimated)
DOE Operating Budget Costs:	$15 M
Staffing (Full-Time Equivalent):	427[1]
Capital Investment (Plant and Equipment):	$31 M[2]
Number of Acres:	56

Operating Contractor: Iowa State University

Responsible Operations Office: Chicago Operations Office

Principal Program Activities (FY 1982 Estimated):[3]

Materials Sciences (42%)
Chemical Sciences (19%)
Fossil Energy (11%)
Biological and Environmental Research (5%)
High Energy Physics (4%)
Nuclear Physics & Nuclear Sciences (2%)
Engineering, Mathematical & Geosciences (2%)
Univeristy Research Support (2%)
Nuclear Energy (1%)
Miscellaneous DOE Programs (5%)[4]
Work for Others (6%)
  Nuclear Regulatory Commission (1%)
  Department of Defense (3%)
  Others (2%)

[1]Total Laboratory Staff.
[2]Current Book Value.
[3]Percentages reflect direct staff (full-time equivalent).
[4]Programs less than 1% are aggregated in this category.

ARGONNE NATIONAL LABORATORY
Argonne, Illinois

The Argonne National Laboratory (ANL) provides advanced nuclear technology research and developmental support to the breeder reactor and other fission reactor programs, and maintains a substantial, diversified capability in physical and biological sciences in support of reactor efforts. Future efforts in the fossil area center on advanced process development, the materials technology, and instrumentation and controls systems engineering. In basic research, the largest effort is in the area of general materials studies. High energy physics and nuclear physics will continue to play a significant role.The consequences of the utilization of particular energy technologies are addressed through studies of health-related problems and the environment. The laboratory has a program to work closely with university professors on sabbatical leaves and sponsors a variety of programs providing opportunities for students through student-laboratory staff interaction.

Argonne is engaging in a number of activities aimed at improving industrial interactions, including involvement in the joint IRI/National Laboratory Task Force, as well as others

Statistics:	**FY 1982 (Estimated):**
DOE Operating Budget Costs:	$210 M
Staffing (Full-Time Equivalent):	4,538
Capital Investment (Plant and Equipment):	$545 M[1]
Number of Acres:	2,245

Operating Contractor: The University of Chicago in cooperation with the Argonne Universities Association

Responsible Operations Office: Chicago Operations Office

Principal Program Activities:

Nuclear Energy (36%)
Basic Energy Sciences (17%)
Conservation and Renewable Energy (9%)
Biology (7%)
Fossil Energy (6%)
High Energy Physics (3%)
Nuclear Physics (3%)
Environmental Protection, Safety, and Emergency Preparedness (2%)
Fusion (2%)
Defense Programs (1%)
Work for other DOE (1%)
Miscellaneous DOE Programs (2%)
Work for Others (11%)
- Nuclear Regulatory Commission (5%)
- Department of Defense (1%)
- Others (5%)

Major Active Facilities:

Experimental Breeder Reactor II
Hot Fuels Examination Facilities
TREAT Reactor
Zero Power Reactors
Zero Power Plutonium Reactor

Major User Facilities:

Intense Plused Neutron Source I
Facility for High Resolution Atomic Spectroscopy
Argonne Tandem Linac Accelerator

[1]Includes Argonne National Laboratory West, Idaho.

BROOKHAVEN NATIONAL LABORATORY
Upton, New York

The Brookhaven National Laboratory (BNL) conceives, develops, constructs, and operates complex large research facilities which are used to study fundamental properties of matter and are shared with university and industrial scientific communities (e.g., the National Synchrotron Light Source and the Alternating Gradient Synchrotron). The laboratory conducts basic and applied research in technology base areas, in support of research facilities, and to discover important new directions for research. Major disciplinary strength is found in the areas of high energy, nuclear and solid state physics, chemistry, and biology. Biological and medical programs include studies of the effects of radiation and of chemical substances involved in the production and use of energy. Other research programs include meteorological dispersion, atmospheric chemistry, pulmonary physiology, and inhalation toxicology. The National Synchrotron Light Source gives the laboratory a unique position in the breadth of sophisticated facilities available to all areas of the physical and biological sciences. Over 1,000 faculty and 160 students have guest appointments enabling them to carry out research at BNL facilities. In addition, there are five different programs which provide 150 students with a variety of training opportunities. The National Synchrotron Light Source will greatly increase the number of faculty and students carrying out research programs at the laboratory. This facility will also be used extensively by industrial scientists; presently, nine of the 29 initial beam lines at the facility are partially or completely supported by the industrial community.

Statistics:

	FY 1982 Estimated:
DOE Operating Budget Costs:	$125 M
Staffing (Full-Time Equivalent):	3,300
Capital Investment (Plant and Equipment):	$469 M
Number of Acres:	5,265

Operating Contractor: Associated Universities, Inc.

Responsible Operations Office: Chicago Operations Office

Principal Program Activities (FY 1982 Estimated):

High Energy Physics (39%)
Basic Energy Sciences (19%)
Environmental Research and Development (6%)
Life Sciences Research and Nuclear Applications (5%)
Nuclear Physics (3%)
Miscellaneous DOE Programs (10%)
Work for Others (18%)
- Nuclear Regulatory Commission (9%)
- Others (9%)

Major Active Facilities:

National Synchrotron Light Source
Alternating Gradient Synchrotron
High Flux Beam Reactor
Tandem van de Graaff

Major User Facilities:[1]

60" Cyclotron
Scanning Transmission Electron Microscope
Central Scientific Computing Facility
Research Hospital

[1]In addition to those facilities listed under Major Active Facilities column.

LAWRENCE BERKELEY LABORATORY
Berkeley, California

The Lawerence Berkeley Laboratory (LBL) conceives, develops, constructs, and operates complex large research facilities which are shared with university and industrial scientific communities (e.g., Bevalac and Super HILAC). The laboratory capitalizes on its co-location with the University of California to provide a broad range and flexible pool of the scientific talent for research and advanced development with major research programs in high-energy physics, nuclear physics, basic energy sciences, conservation and solar energy, coal research, interial confinement fusion, geochemistry, computer science, and mathematics. LBL has a role in the training of the next generation of scientists and engineers for careers in advanced energy research and technology. Over 500 resident graduate students conduct thesis research at the laboratory and many more use its facilities or perform collaborative research. Participation in energy research programs provides these students with skills in high demand by energy industries. The flow of Ph.D.'s to industry is one of many forms of technology transfer that allows LBL to maintain close and supportive relationships with industry.

Statistics:	**FY 1982 (Estimated):**
DOE Operating Budget Costs:	$84 M
Staffing (Full-Time Equivalent):	2,524
Capital Investment (Plant and Equipment):	$195 M
Number of Acres:	70[1]

Operating Contractor: The Regents of the University of California

Responsible Operations Office: San Francisco Operations Office

Principal Program Activities (FY 1982 Estimated):

Energy Research (67%)
Conservation & Renewable Energy (8%)
Fossil Energy (2%)
Miscellaneous DOE Programs (4%)
Work for Others (19%)
- Nuclear Regulatory Commission (4%)
- Department of Defense (2%)
- Other (13%)

Major Active and User Facilities:

Bevatron
Super HILAC
88" Cyclotron
High Speed Computers

[1] Leased to the Government

LAWRENCE LIVERMORE NATIONAL LABORATORY
Livermore, California

The primary role of Lawrence Livermore National Laboratory (LLNL) is the research, development, and test of nuclear weapons designs. Expertise developed in this area is also supplied to related areas of defense research such as inertial confinement fusion, nonnuclear ordnance, and particle-beam technology. LLNL also undertakes research and development technologies of national interest, primarily in the field of energy, where the skill or facilities requirements are unique and synergistic to the on-going weapons effort. As a result the Laboratory has active on-going programs in magnetic fusion energy, laser isotope separation, biomedical and environmental studies, in-situ coal gasification and oil shale retorting, energy storage systems, transportion energy conservation, and solar energy research and development. Within these programs, LLNL interacts with both universities and private industry through faculty/student training, consulting, and technology transfer activities.

Statistics:

	FY 1982 (Estimated):
DOE Operating Budget Costs:	$450 M
Staffing (Full-Time Equivalent):	7,200
Capital Investment (Plant and Equipment):	$445 M[1]
Number of Acres:	631

Operating Contractor: University of California

Responsible Operations Office: San Francisco Operations Office

Principal Program Activities (FY 1982 Estimated):[2]

Defense Programs (51%)
Magnetic Fusion (10%)
Laser Fusion Energy (10%)
Isotope Separation (6%)
Energy Programs (3%)
Biomedical/Environmental (3%)
Miscellaneous DOE Programs (3%)
Work for Others (14%)
- Department of Defense (8%)
- Nuclear Regulatory Commission (3%)
- Other Federal Agencies (3%)

Major Active Facilities:[3]

Argus Laser Facility
Shiva Laser Facility
Nova Laser Facility (in progress)
100 MeV Accelerator Facility
National Defense Support Livermore Computer Center
Gaseous and Metallurgical Facility (Plutonium & Tritium)
Magnetic Fusion Energy Facility (in progress)
14 MeV Rotating Target Neutron Source
Mirror Fusion Test Facility (MFTF-B) (in progress)
Tandem Mirror Experiment (TMX)
National Magnetic Fusion Energy Computation Center
Fusion Target Development Facility (in progress)
High Explosive Flash Radiograph Facility
Weapons Materials R&D Facility (in progress)

[1]Current book value (including work in progress less accumulated depreciation).
[2]Percentages reflect Direct Full-Time Equivalent program effort (excluding Construction/Equipment).
[3]$5 million or more acquisition cost.

LAWRENCE LIVERMORE NATIONAL LABORATORY (Continued)

Major Active Facilities:[1]

Management Support Center—Core 1
High Explosive Application Facility (in progress)
Advanced Isotope Separation Facility (in progress)
Advanced Test Accelerator Facility (in progress)
Large Optics Diamond Turning Machine (in progress)
High Explosive Processing and Test Facility

[1] $5 million or more acquisition cost.

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico

The Los Alamos National Laboratory's (LANL) primary mission is the application of science and technology to problems of national security, that is, to the maintenance of a strong defense, the fulfillment of arms control commitments,and the guarantee of a secure energy supply for the future. In carrying out this mission, the laboratory serves as a liaison between research in academia and industry and complements the activities of both. Major programs include developing nuclear warheads, designing and testing advanced technology concepts, and maintaining an innovative weapons design program. In nuclear fission,programs include separating isotopes of uranium by laser induction, testing advanced reactor fuel elements, modeling reactor accident results for the Nuclear Regulatory Commission, evaluating biomedical consequences of nuclear energy production, and developing effective nuclear waste disposal methods. In nuclear fusion, programs include magnetically confined plasma devices (especially high-beta devices), laser-induced fusion, and safe handling techniques for large quantities of tritium. Other programs include nonnuclear energy, basic energy science, and technology utilization.

Statistics:

	FY 1982 (Estimated):
DOE Operating Budget Costs:	$420 M
Staffing:	6,770[1]
Capital Investment (Plant and Equipment):	$322 M[2]
Number of Acres:	27,500

Operating Contractor: University of California

Responsible Operations Office: Albuquerque Operations Office

Principal Program Activities:

Weapons (48%)
Nuclear Physics (8%)
Magnetic Fusion (4%)
Advanced Isotope Separation Technology (4%)
Verification & Control (3%)
Breeder (3%)
Safeguards (2%)
Nuclear Materials Production (2%)
Miscellaneous DOE Programs (11%)
Other DOE (7%)
Work for Others (8%)
- Nuclear Regulatory Commission (2%)
- Department of Defense (3%)
- Other (3%)

Major Active Facilities:

800 Million Electron-Volt Linear Proton Accelerator (LAMPF)
Weapons Neutron Research Facility
Stable Isotopes Production Facility
20 Terrawatt CO_2 Gas Laser Facility
8 Megawatt Nuclear Reactor
Plutonium Research Facility
Plutonium Heat Sources Fuel Production Facility
National Security Resources and Studies Center

Major User Facilities:

Clinton P. Anderson Meson Physics Facility (LAMPF)
Central Computing Facility
Hot Dry Rock Project (Fenton Hill)

[1]Figures are based on Full-Time Regular Employees.
[2]Current Book Value (excludes construction work in progress).

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee

The Oak Ridge National Laboratory (ORNL) primarily supports the fission nuclear fuel cycle and magnetic fusion energy development (advanced toriodal devices,such as Tokomak and Elmo Bumpy Torus) through scientific research and technology; identifies and solves generic research problems in energy technologies such as materials, separation techniques, chemical processes and biotechnology; and is the major national source of production of stable and radioactive isotopes. Energy technology development at ORNL also includes other important efforts in residential and commercial energy conservation, renewable energy sources, and coal conversion and utilization. ORNL expends special effort to involve industry in its programs and to encourage cooperative uses of facilities, both formally in users' groups and informally through professional contacts and participation. Similarly, the Laboratory provides universities with ready access to major research facilities, state-of-the-art research capabilities, training facilities for faculty and students, and an opportunity for collaborative research in areas where these sources are not available to universities.

Statistics:	**FY 1982 (Estimated):**
DOE Operating Budget Costs:	$278 M[1]
Staffing (Full-Time Equivalent):	4,950
Capital Investment (Plant and Equipment):	$250 M[2]
Number of Acres:	10,270

Operating Contractor: Union Carbide Corporation, Nuclear Division

Responsible Operations Office: Oak Ridge Operations Office

Principal Program Activities:[3]

Fission Energy Development (24%)
Basic Physical Science (21%)
Biomedical and Environmental Sciences (12%)
Fusion Energy (9%)
Conservation and Renewable Energy (5%)
Fossil Energy (4%)
Miscellaneous DOE Programs (6%)
Work for Others (19%)
- Nuclear Regulatory Commission (8%)
- Department of Defense (1%)
- Others (10%)

[1]Costs based on the FY-82 column of Oak Ridge Operations Office's FY-83 budget.
[2]Current book value of plant and equipment including construction work in progress as of September 30, 1981.
[3]Percentages reflect direct staff Full-Time Equivalents.

OAK RIDGE NATIONAL LABORATORY (Continued)

Major Active Facilities:

Isotopes Separation Facility
High Flux Isotope Reactor
Electron Linear Accelerator
Transuranium Processing Plant
Oak Ridge Research Reactor
Oak Ridge Isochronous Cyclotron
High Level Radiochemical Laboratory
Materials Processing Laboratory
Thorium Uranium Fuel Recycle Facility
High Radiation Level Examination Laboratory
Enviromental Sciences Laboratory

Major User Facilities:

Holified Heavy Ion Research Facility
EN-Tandem Accelerator
Oak Ridge Electron Linear Accelerator (ORELA)
Neutron Scattering Facility
National Center for Small-Angle Scattering Research
Ion-Solid Interactions Laboratory
Shared Research Equipment Program (SHARE)

PACIFIC NORTHWEST LABORATORY
Richland, Washington

The mission of the Pacific Northwest Laboratory (PNL) is the advancement and use of multi-energy scientific and engineering technology for national security and the nation's energy needs. In accomplishing this mission, high priority is given to safe and reliable nuclear energy, and to promising new concepts and technologies for operations at Hanford. Areas of disciplinary strengths and concentration include nuclear waste process development, nuclear fuel development and evaluation, spent fuel storage reprocessing, inhalation toxicology, bioelectromagnetics, biology, ecology, atmospheric sciences, corrosion chemistry, biomass research, nondestructive testing and evaluation, materials characterization and research, chemical engineering, health physics technology, and energy economics and policy analyses. The laboratory provides a core capability for effectively utilizing the strengths of the universities and the private sector and has traditionally developed and maintained strong ties with the academic community. That resource is utilized through cooperative exploratory research efforts to accelerate application of new ideas, scientific research support to PNL efforts on team assignments, and exchange of staff and student research. Industry and utilities participate with PNL staff in efforts to develop advanced technology, to improve existing instruments or develop new ones,and to investigate and demonstrate energy conservation and conversion techniques.

Statistics:

	FY 1982 (Estimated):
DOE Operating Budget Costs:	$98 M
Staffing (Full-Time Equivalent):	1,975
Capital Investment (Plant and Equipment):	$65 M
Number of Acres:	Not Applicable[1]

Operating Contractor: Battelle Memorial Institute

Responsible Operations Office: Richland Operations Office

Principal Program Activities (FY 1982 Estimated):

Fission (25%)
Defense (17%)
Life Sciences (16%)
Conservation (7%)
Renewable (7%)
Basic Sciences (5%)
Miscellaneous DOE Programs (3%)
Work for Others (20%)
  Nuclear Regulatory Commission (15%)
  Department of Defense (3%)
  Others (2%)
Biomass Experimental Unit
Geophysical and Astronomical Observatory
National Enviromental Research Park

[1]PNL facilities are in an area shared with Hanford Engineering Development Laboratory and UNC Nuclear Industries.

PACIFIC NORTHWEST LABORATORY (Continued)

Major Active Facilities:

Two Life Science Laboratories
Marine Research Laboratory
Meteorological Center
Critical Mass Laboratory
Nuclear Waste Vitrification Laboratory
Materials Reliability Center
Steam Generator Examination Facility

Major User Facilities:

Critical Mass Laboratory

SANDIA LABORATORIES
Albuquerque, New Mexico; Livermore, California; Tonopah, Nevada

Sandia Laboratories' principal mission has been and remains research, development, and engineering of nuclear weapon systems, except for the nuclear explosive. The result of this effort is the existence of a national stockpile of nuclear weapons that are safe, secure, reliable, under strict control, and operationally ready. Sandia is also responsible for major energy programs in fossil, solar, fission, and basic energy sciences. Its strength lies in its ability to conduct large, interdisciplinary engineering projects that are both technologically "risky" and sophisticated. Fundamental understanding and technological development are melded to create an environment conducive to generating new products and processes that are unlikely to be produced in either university or industrial laboratories. These new technologies are transmitted to the private sector through journals, workshops, and other information transfer mechanisms, and significantly contribute to the nation's scientific and economic prosperity.

Statistics:	FY 1982 (Estimated):
DOE Operating Budget Costs:	$610 M
Staffing (Full-Time Equivalent):	7,950
Capital Investment (Plant and Equipment):	208 M[1]
Number of Acres:	3,140 (Albuquerque) 185 (Livermore)

Operating Contractor: Western Electric Company

Responsible Operations Office: Albuquerque Operations Office

Principal Program Activities:[2]

Defense Programs (67%)
Conservation and Renewable Energy (6%)
Nuclear Energy (5%)
Fossil Energy (3%)
Energy Research (3%)
Environmental Protection, Safety, and Emergency Preparedness (1%)
Work for Others (15%)
- Department of Defense (8%)
- Nuclear Regulatory Commission (5%)
- Others (2%)

Major Active Facilities:[3]

Particle Beam Fusion Facility
Nuclear Safeguards and Security Facility
Combustion Research Facility
5-megawatt Solar Central Power Test Facility
Center for Radiation-hardened Microelectronics
Tonopah Test Range
Radiation/Simulation Facilities

Major User Facilities:

Combustion Research Facility
Solar Central Power Test Facility
Tonopah Test Range
Radiation/Simulation Facilities

[1]Current Book Value (Excludes Construction Work in Progress).
[2]Percentages reflect direct staff (full-time equivalent).
[3]Major construction line items only.

ATTACHMENT C

Significant Accomplishments Illustrative of Multiprogram National Laboratory Research

AMES LABORATORY

- The Ames Laboratory developed efficient reduction and purification processes for uranium, thorium, the rare earths, zirconium, hafnium, yttrium, and vanadium. All of the processes have been adopted by industry, and all are in use today. Essentially all of the uranium used in the Western world has been prepared by the Ames process, and the entire rare earth industry is largely dependent upon the basic separations and chemical, metallurgical, and materials characterization achievements of this Laboratory (1940 to present).
- The development of the inductively coupled plasma atomic-emission spectroscopy method for multi-element analysis was carried out at the Laboratory. The method is very fast, requires minute amounts of sample, and permits simultaneous identification of up to 50 elements: for most of these elements, this method is more sensitive than any other. Commercial instruments based on this development have been introduced: six U.S. and 11 foreign companies are now marketing such instruments at a sales rate of about $100 million per year (1970s).
- Development of a ductile, composite superconducting wire suitable for large-scale magnets in the 12- to 14-tesla range was carried out by an interdisciplinary team of metallurgists and solid state physicists at Ames Laboratory. The material is easy to fabricate and has the high strength and strain tolerance needed for toroidal field magnets in Tokamak fusion reactors (1970s to present).
- The Ames Laboratory developed the basic science for sampling, isolating, and quantitating the trace organic compounds in water. The isolation techniques have increased detection power approximately 10,000-fold for most compounds of environmental interest. The methodology has been adopted nationally and internationally by government, university, and industrial laboratories (mid to late 1970s).
- Recently a reactive radio frequency sputtering method for the preparation of hydrogenated amorphous silicon films for solar cells was developed here. The method permits the preparation of large-area films needed for solar panels while retaining the careful control of the local environment of the hydrogen ions, which is needed for high performance (1978 to present).
- Very recently a method based on high-resolution solid state nuclear magnetic resonance in coal samples has been developed for determining the sizes of the polynuclear aromatic rings in the molecular structure of coal. These results, compared with similar results on liquid fuels produced from coal, are used to study the effects of the chemical processing steps in liquefaction (1978-1980).
- The Laboratory has also recently completed the development of a laser/mass spectrometer probe capable of detecting 62 elements present in concentrations as low as 1 ppb in phases of solids whose dimensions are as small as 10 to 20 μm and it is applicable to metals, semiconductors, and insulators. Accurate analyses can be made without the use of standards (mid-1970s to present).
- Chemical engineers and materials chemists at the Ames Laboratory have developed methods for improved control of the complex chemical equilibrium governing the separation of plutonium from uranium in fuel processing. The programs developed in the work are now being used in nuclear safety and nuclear safeguards programs in the United States (1973-1976).
- The development of a liquid junction solar cell using WSe_2 and $MoSe_2$ with efficiences of 10% and 9.5% and no detectable photocorrosion of the electrodes after extended illumination was recently carried out by an interdisciplinary group from the Materials Chemistry and Solid State Physics divisions at Ames (1977-1980).
- Ames Laboratory scientists are responsible for the recent development of a provisional international practical temperature scale for use by the entire scientific community. A large portion of fundamental research between 0.5 and 35 K was done by the Laboratory, and the scale was adopted by the International Commission on Weights and Measures (CIPM) (1975-1976).

ARGONNE NATIONAL LABORATORY

- Water-cooled nuclear reactor research, design, and development at Argonne National Laboratory contributed significantly to the establishment of the nuclear power industry and in the nuclear-powered submarine. The Laboratory still provides reactor and reactor waste safety information (1946 to present). This capability was applied to the following projects:
  1. design of the first land-based prototype submarine reactor,
  2. design of the first reactor using heavy water as a moderator and coolant,
  3. basic design of the Savannah River production reactors, and
  4. development of the boiling water reactor concept [Boiling Reactor Experiments (BORAX), Experimental Boiling Water Reactor (EBWR)].

- Liquid-metal Cooled Fast Breeder Reactor (LMFBR) research, design, and development at Argonne provided the technology foundation for these reactors and continues to provide component and materials testing and evaluation. It has accumulated 16 years of LMFBR operational experience in the production of electricity. This research produced the following advances:
  1. design of the first successful breeder reactor (EBR-I), which produced the first usable amounts of nuclear-generated electricity;
  2. development of fast reactor and high-temperature reactor fuel materials; and
  3. development of the world's first transient reactor test facility (TREAT) to study fuel behavior during sudden power surges (1946 to present).

- A prototype superconducting linear heavy-ion accelerator is operational. When a total of seven modules are completed, the Argonne Tandem-Linac Accelerator System (ATLAS) will be able to provide 1.5 GeV particles, previously unavailable, that will improve understanding of nuclear binding forces (1979 to present).

- Intense Pulsed Neutron Source-I (IPNS-I) provides the world's most powerful source of non-reactor neutrons, which will be used to study radiation effects in fission and fusion reactor materials. Other applications will include areas of physics, chemistry, and biology (1971 to present).

- Zero Gradient Synchrotron (ZGS) acceleration of polarized protons was used to study spin-spin interaction between protons at high energy. Contrary to the existing belief, spin effects were shown to be large (1971-1979).

- Liposome encapsulation, the technique of coating minute amounts of a drug with naturally occurring fatty substances called phospholipids, was developed at Argonne. The microscopic capsules formed by this technique penetrate individual cells, where the fatty coating is dissolved by enzymes and the drug is allowed to do its work without having been weakened or diluted by the body's defense systems. When applied to cancer chemotherapy,liposome encapsulation allows the destruction of diseased cells from within, while leaving nearby cells unharmed. Eleven companies are currently using the technique to improve the efficiency of their anti-cancer agents (1973 to present).

- ISO-DALT, a two-dimensional electrophoretic system that separates and maps human serum proteins together with TYCHO image analysis and the KEPLER data base, will become a powerful diagnostic tool for extremely early detection of many diseases in man and will be applicable to large populations (1978 to present).

- Mathematical software has been designed and developed, including EISPACK for eigenanalysis, FUNPACK for approximations of special functions, LINPACK for solution of linear systems, MINPACK for numerical optimization, and SPEAKEASY for matrix manipulations. There is also AURA, which functions as an "automated reasoning assistant" and interacts with the scientist to solve problems. Distribution on EISPACK alone includes over 1000 research centers in over 70 countries (1972 to present).

- The world's largest high-field superconducting magnets, used in magnetohydrodynamics generators of electricity and in high-energy-physics bubble chamber experiments, have been designed and developed (1963 to present).

- Fluidized-bed combustion is a technology that has been developed to permit the use of high sulfur coal. Ninety percent of the sulfur combines with limestone during combustion, thereby reducing air pollution. Attention is now focused on recycling the limestone (1963 to present).

BROOKHAVEN NATIONAL LABORATORY

- The large particle accelerators that Brookhaven National Laboratory (BNL) has designed, built, and operated as national facilities have been the sources of many discoveries in particle physics which have led to a deeper understanding about the nature of matter. The first observation of a charmed baryon was made at BNL; and two recent Nobel prizes in physics, 1976 and 1980, were awarded for work carried out at BNL: the discovery of the J/psi particle in 1974 and the experiment which showed the violation of a fundamental symmetry principle in 1963.

- The magnetic principle of alternating gradient strong focusing discovered at BNL has been, and continues to be, the critical advance upon which construction of synchrotrons capable of accelerating protons to 100's of GeV depends. This fundamental discovery had two important consequences: it greatly reduced the cost of accelerators by allowing much smaller aperatures, and it provided a means of transporting extracted or secondary beams (produced by interactions of the primary beam with a target) to experimental apparatus located far from the accelerator. Both of these applications are essential to all modern proton synchrotrons, which now operate at energies as high as 500 GeV (1952 to present).

- Research reactors developed at BNL have consistently been at the forefront of design of these very important research devices. The Brookhaven graphite research reactor in 1950 became the first peace-time research reactor; it supported most of the free world's neutron beam research until 1966, when the Brookhaven High Flux Beam Reactor (HFBR) came on line. The HFBR is now the nation's most sophisticated and most heavily used reactor for neutron beam research. Recent improvements include increasing the power by 50% and installing a cold neutron source (i.e., a source of very-low-energy neutrons used in solid-state physics research); these improvements assure continued preeminence in the research reactor field.

- Neutron cross section experiments and criticality experiments on the properties of lattices of uranium rods in water conducted at BNL provided the basis for the design of light water reactors that now produce most of the world's nuclear-generated electricity. In addition, the compilation, evaluation, and storage of data from the neutron cross section experiments and, more recently, from other nuclear experiments have led to the creation of a central repository for most of the nuclear physics data generated throughout the world (1950s to present).

- Neutron scattering experiments at BNL's High Flux Beam Reactor have definitely established the nature of the magnetic state and its competition with superconductivity. This crucial step in relating these two very fundamental and technologically important properties of materials will eventually lead to deeper understanding and more sophisticated applications of these properties (1976 to present).

- By the middle of the 1970s, sufficient data were obtained from a 600-ton solar neutrino detector situated 1 mile underground to show that either our current views of the details of the nuclear reactions generating the sun's energy are incorrect or that our understanding of the fundamental properties of neutrinos is not complete. Since both of these possibilities are of great interest, a new experiment designed to eliminate one of them is underway.

- The first demonstrated transformation of human cells in culture by ultra-violet light was shown at BNL; this discovery now opens the way for laboratory studies of cancer-producing mechanisms (1980 to present).

- The first correlation between the ability to repair damage to DNA and the life span of different mammalian species was discovered by a BNL scientist who is now investigating the relationship of DNA repair to aging in humans (1974 to present).

- The invention at BNL of a procedure by which the short-lived radiopharmaceutical ^{99m}Te could be effectively distributed and used by the medical community started a new generation of nuclear medicine applications. This isotope continues to account for approximately 80% of the one mission administrations of radiopharmaceuticals per year in the U.S. and is the basis of a $100 million commercial enterprise, domestically.

BROOKHAVEN NATIONAL LABORATORY (Continued)

• The labeling of 2-fluro-2-deoxy-d-glucose with radioactive ^{18}F at BNL and use of this radiopharmaceutical in conjunction with positron-emission transaxial tomography (PETT) has initiated widespread activity in many new areas of medical research: measurement of regional metabolic activity at accurately determined locations inside the brain is now possible. The technique has led to a much detailed understanding of a whole range of phenomena (e.g., drug response) and diseases (e.g., senility, stroke, and schizophrenia) that affect the brain. The National Institutes of Health (NIH) are now supporting about ten centers to carry out this type of work (1976 to present).

LAWRENCE BERKELEY LABORATORY

- The Lawrence Berkeley Laboratory (LBL) has been responsible for numerous major advances including the invention of the cyclotron, the linear accelerator, the synchrotron, and continuing contributions to new particle accelerator concepts and construction projects (1929 to present).
- The creation and identification of 15 new chemical elements, including plutonium, by nuclear synthesis was carried out by scientists at LBL (1940-1976).
- Particle research conducted by scientists at the Laboratory led to the discovery of the antiproton and numerous excited states of the fundamental particles (1955-1965).
- The Laboratory became one of the world's major centers of heavy-ion nuclear physics research by (1) adapting the 88-Inch Cyclotron to the acceleration of heavy ions (1971); (2) connecting the SuperHILAC heavy-ion accelerator to the Bevatron to make the Bevalac (1972); and (3) improving the Bevalac (1981) to provide acceleration of ions as heavy as uranium to multi-billion-volt energies, a capability unavailable anywhere else in the world. SuperHILAC, Bevalac, and 88-Inch Cyclotron accelerators serve as national facilities for nuclear physics and biomedical research (1971 to present).
- The LBL was responsible for the founding of the National Center for Electron Microscopy equipped with instruments of highest energy and highest resolution (1980 to present).
- The Laboratory was also responsible for the founding of the science of nuclear medicine (1935), the continued development of instruments and techniques for the beneficial use of gamma and particle radiations (1935 to present), and the exploration of use of heavy ions for treatment of cancer.
- The Laboratory has contributed significantly to discoveries and developments in high energy physics: for example, discovery of the Ψ family of particles, the discovery of charmed particles, the design and construction (with Stanford Linear Accelerator Center) of the Positron-Electron Project accelerator, the design and construction of the Mark I and II massive detector systems, the design of the Time Projection Chamber superconducting magnet, and the development of stochastic beam cooling (1974 to present).
- The Laboratory has also done research and development on particle injection into fusion reactors for heating and fueling and design and construction of neutral beam injectors for Lawrence Livermore National Laboratory's 2X-IIB, Princeton's Tokomak, and General Atomic's Doublet III (1974-1981).
- The large-scale field experiment was conducted in an iron mine in Stripa,Sweden, to measure rock characteristics significant to underground storage of nuclear wastes (1976).
- The LBL has been responsible for the development of instruments now used in hundreds of university and corporate laboratories for precise measurement of gamma radiation, x-rays, nuclear particles, chemical elements, chemical compounds, magnetic field strengths, and other properties (1950-present).

LAWRENCE LIVERMORE NATIONAL LABORATORY

Weapons

- Since its establishment in 1952, LLNL, in conjunction with Los Alamos and Sandia, has continued to function as an integral scientific and technical element of the nation's nuclear weapons program including all facets of nuclear weapon technology and the supporting scientific and engineering disciplines. Particularly, significant achievements have been made in such areas as reduction in size and weight, and enhanced safety, flexibility, and military effectiveness of nuclear weapons. These advances in design have enabled the defense community to provide the nation with increasingly effective warhead capabilities for its nuclear weapons systems.

Nonweapons

- Under inertial confinement fusion, LLNL developed the technology for 100 TW Nd: glass laser systems. This technology, now adopted as the international workhorse for ICF research, was successfully transferred to U.S. industry in 1975. In addition, LLNL developed the first ultrafast (~20 psec) x-ray streak camera (now becoming commercialized) and the first use of micro-fabrication technology for high resolution imaging of alpha particles and x-rays (1976-1978). In integrated fusion experiments, the Laboratory provided the first confirmation of laser induced thermonuclear reactions (1975), the first demonstration of energy scalable ablative implosions (1976), and achieved a systematic scaling of imploded fuel density, up to 100 times liquid density, on the Shiva laser facility (1978-1979). Also definitive improvements in target performance at visible and ultraviolet wavelengths were demonstrated on the Argus laser facility. For fusion energy applications, LLNL researchers conceived and assessed the excimer laser driver and the HYLIFE reaction chamber, which features a long-lived (30 year) liquid lithium "first wall" (1977-1981).
- Within the Atomic Vapor Laser Isotope Separation (AVLIS) Program, researchers separated uranium isotopes (1974); demonstrated macroscopic uranium enrichment utilizing critical subsystems scalable to production plant size (1978); developed a high-power tunable (isotopically selective) laser system which is economically competitive (1981); and activated a full-scale uranium vaporizer unit (1981).
- Livermore's involvement in magnetic fusion research dates from the founding of the laboratory in 1952. As lead laboratory for the National Magnetic Mirror Program, LLNL achieved thermonuclear plasma temperature with near-classical confinement in the 2X-IIB experiment (1978); demonstrated the adaptation of the mirror concept of an efficient reactor design in TMX (1980); and developed, with LBL large neutral high-field superconducting magnets Baseball II and Mirror Fusion Test Facility, MFTF (1981), which enhance related energy technologies like magnetohydrodynamics.
- Livermore has pioneered in underground engineering and experiments for weapons applications. Transfer to nonweapons applications includes rock fracturing for fossil energy applications and incorporating high-level radiation wastes in crystal lattices of synthetic rocks that are related to natural minerals with extremely long-period stability. In situ coal gasification was demonstrated in experiments at Hoe Creek, Wyoming (1979), that produced a medium BTU gas suitable for chemical synthesis or upgrading to pipeline quality. Industry has contributed resources to this effort.
- Beginning in 1972 and building on the foundation laid by LANL, LLNL has been a world-wide leader in the development of analytical cytology (flow cytometry, flow sorting, computer-based scanning microscopy, cytochemistry) and its application to energy-related toxicology. The laboratory has founded the new field of flow cytogenetics in which chromosomes are analyzed at high speed and resolution, and can, for the first time, be purified by type. LLNL researchers are also pioneering the application of analytical cytology to rare event detection, most noteworthy of which is the detection of somatic mutant cells in human blood. A practical assay for human somatic mutation would be a major breakthrough in the interface between preventive medicine and modern technological development.
- The Laboratory was also responsible for the development of the Atmospheric Release Advisory Capability (ARAC) System for predicting the exposure consequences from accidental releases of radioactivity with real-time communications to system sites. Conceptual studies were done in 1972; limited implementation occurred between 1974 and 1976; and the system was applied to the Three Mile

LAWRENCE LIVERMORE NATIONAL LABORATORY (Continued)

Island (TMI) accident and Kemeny Commission studies in 1979 and to the TMI Purge in 1980.

- Precision engineering and machining techniques for the design, fabrication,and inspection of highly precise mechanical workpieces have been under continual study and development since 1955. Two diamond turning machines were constructed (1968-72) for unprecedented accuracy in the machining of parts, and a third is in development. Assistance has been provided in transferring this technology to industry.
- A systems study of the aluminum-air power cell and its use in automotive propulsion, including performance, cost, and energy efficiency estimates was completed (1980). With industrial participation, the Laboratory is now developing and evaluating a prototype metal-air power cell as an automotive energy source with the range, acceleration, and rapid refueling capability of current internal-combustion engines.

LOS ALAMOS NATIONAL LABORATORY

Weapons

- Established in 1943, Los Alamos National Laboratory (LANL) developed the first fission and thermo-nuclear weapons. In conjunction with Sandia and LLNL, LANL has continued to maintain U.S. superiority in all facets of nuclear weapons technology and supporting scientific and engineering disciplines. Enhanced safety, flexibility, and military effectiveness have been produced through a reduction in size and weight of the weapons. These advances in design have enabled LANL to provide increasingly effective warhead capabilities for integration into a number of defense systems serving every branch of service.

Nonweapons

- Examples of major Los Alamos accomplishments before 1970 include designing, building, and operating the world's first plutonium-fueled fast reactor and the world's highest temperature and power density fission reactors, thereby establishing possibilities for advanced fission systems and eventual process heat applications. Los Alamos also achieved the first laboratory demonstration of controlled thermo-nuclear fusion, thereby establishing the possibility of eventual electricity production from fusion reactions.

- The Molecular Laser Isotope Separation (MLIS) Process for the enrichment of uranium has been developed to the point of demonstrating process feasibility. If developed to production scale, the MLIS process would result in a significant reduction in energy consumption and cost compared to diffusion and centrifuge technology. In response to the needs of the MLIS Program, state-of-the-art advances have been made in the area of laser research and development. The high-power, electric discharge excimer laser operating on all rare gas-halogen combinations has been successfully developed primarily at Los Alamos and by the Laboratory's direct contractors. In addition, LANL has pioneered the development of pulsed isotopic carbon dioxide lasers having long operating lifetimes and a high degree of stability. LANL contractors have produced the first high repetition rate, stable isotopic carbon dioxide lasers at the kilowatt/kilohertz level.

- Fast-reactor fuels of plutonium carbide developed by Los Alamos successfully attained specific power production (burnup) of over 150,000 mwd/ton(1981). This is much higher than that offered by present oxide fuels now used in breeder reactors. The new fuel has also demonstrated the capability of undergoing severe heating transients without performance degradation, an important safety feature. The combination of the improved thermal, mechanical, and neutronic performance of carbide fuel could lead to significant savings in fast-reactor fuel fabrication costs and in overall plant and operating costs as well.

- Special plutonium fuels using a Los Alamos oxide of ^{238}Pu and ^{18}O now provide long-life, stable, low background heat sources which generate electricity for experiments on the moon and on the Voyager spacecraft. Newly developed general purpose heat sources employing the same material will be combined in modular arrangements to power the Galileo Deep Space Probe and the Polar Orbiter solar studies mission. The same material, used in smaller radioactive heating units, has numerous space and terrestrial applications.

- Reactor transient codes designed by Los Alamos have been used to understand the behavior of complete nuclear reactor systems under accident conditions. These computational methods were successfully applied shortly after the Three Mile Island accident to reproduce that plant's behavior during the accident. Developments now under way suggest that this computational skill can be incorporated into high-speed microprocessor units at the power plants. This would give their operators rapid analysis during the course of a potential accident, guiding their response more surely to prevent the accident or reduce its consequences.

- The idea of extracting geothermal energy from structurally sound subterranean "hot dry rock" found nearly everywhere was conceived at Los Alamos eight years ago and has already had a first demonstration of technical feasibility. Heat transfer surfaces were created by fracturing the hot rock between deep drill holes and connecting the holes above ground to form the world's first closed loop geothermal energy system. This environmentally-clean recirculating system produced an average 2.0 megawatts (MW) of power for over 10,000 hours, and a portion of this was regularly used to generate onsite electricity up to 60 kilowatts (kw). Now, under joint sponsorship of the USDOE and the governments of West Ger-

many and Japan, a larger (35 MW) engineering system is being constructed (in 300°C rock at 4050 m depth) to demonstrate commercial feasibility. The project has already advanced that state-of-the-art in hard rock drilling has pioneered in deep drilling (two-three miles) at high temperatures. Many of the new high-temperature downhole tools and instruments developed for this work have already been adopted by industry. Prospecting techniques developed at the Laboratory are now being used to define and map the more readily accessible parts of this enormous nationwide resource.

- Flow cytometry, developed at Los Alamos, is automatic high-speed sorting of thousands of specific cells, chromosomes, etc., per second using laser illumination of individual cells to measure and select cell size, structure, and chemical composition (1972). This newly transferred technology is already worth several million dollars annually to industry. It is used in health research laboratories and is entering medical and clinical use. It is being applied to disease diagnosis and identification of genetic diseases and tumor cells; it is also being used to study the effects of radiation therapy, drugs, or toxic agents on cells and to develop chemotherapeutic cancer treatment schedules. An emerging application may make it possible to quantify the importance of chromosome aberrations as biological markers for chemical exposure (1972).

- Nonconventional hard materials are a very recent development that may replace tungsten carbide-cobalt in armor-piercing munitions, machine tool bits, mining drilll bits, and other applications where high hardness and abrasion resistance are important. These materials do not require strategic materials or cobalt and will use less tungsten. This development has both commercial and defense applications (1981).

- Accelerator developments at Los Alamos have found many practical applications. The mid-1960s discovery of the side-coupled cavity concept greatly increased the efficiency of transferring power to linear accelerator beams and is now adopted almost universally. Recently, LANL has learned how to apply the RF quadrupole bunching and guidance concept successfully to the low-velocity portions of ion linear accelerators. Essentially all such new machines are expected to adopt this technology as well. At the Los Alamos Meson Physics Facility (LAMPF), an accelerator which is nationally and internationally used, researchers have pioneered in the treatment of deep-seated human tumors by pion radiotherapy. Clinical successes and availability of the above technological improvements have encouraged the development of a compact machine especially optimized for hospital use. It is called PIGMI (Pion Generator for Medical Irradiations), and its design concepts are being shared with domestic companies and companies in Japan and Sweden.

- A program for the separation of isotopes of carbon, nitrogen, and oxygen (ICON/L/C) has produced kilogram-per-year quantities of ^{13}C, ^{15}N, ^{17}O, and ^{18}O. The unique 225-m long, cryogenic distillation column of this program is the major source of these isotopes in the Western world. The separated stable isotopes are utilized in physical and biomedical sciences and in environmental studies through basic research programs and extensive cooperative ventures with universities and medical schools.

OAK RIDGE NATIONAL LABORATORY

- Oak Ridge National Laboratory (ORNL) served for over 30 years as the principal developer and reference source for models and techniques to estimate radiation doses received by humans. Essentially all nations have uniformly adopted usage of the ORNL models and techniques through the recommendation of the International Commission on Radiological Protection (1940s to present).

- The Laboratory has developed advanced centrifuge techniques producing pure vaccines and for performing rapid medical diagnoses. These are now in wide-scale commercial use (1965-1975).

- The development of radionuclide production for nuclear medicine applications was initiated at ORNL, and, in conjunction with medical schools and hospitals, the Laboratory developed efficient radiopharmaceuticals as imaging agents to study heart disease and locate brain tumors (1945 to present).

- The first heavy-ion cyclotron was constructed at ORNL, and the field of heavy-ion physics was founded by establishing the general properties of heavy-ion elastic scattering, transfer reactions, and compound nuclear reactions (1950 to present).

- Crucial determinations were made of neutron radiation damage, including radiation-induced creep, in metals and alloys; contributions in this area have been necessary for the development of nuclear reactors (1949 to present).

- Theory and supporting data for the design of heavy section steel vessels were developed at ORNL. The results of this program have provided an assurance of safety necessary for the light-water reactor (LWR) pressure vessel, which has been accepted by regulatory bodies both in the United States and other countries (mid-1960s to present).

- The Laboratory provided rapid and extensive assistance during the Three Mile Island incident, from the beginning until now. Radiochemical, chemical, and isotopic measurements were made, along with a variety of physical tests. ORNL developed the process flowsheet for the cleanup of the water from the containment building. ORNL also resolved the question of why iodine releases were so low and showed that much lower iodine releases than previously predicted would occur in many LWR accident scenarios (1980 to present).

- For nuclear fuel reprocessing, ORNL developed Purex (1953), Thorex (1958),and Remotex (1980). Purex and Thorex processes are now used in all known fuel reprocessing plants throughout the world. Remotex is a fully remote processing concept which has been used for most radioisotope systems and also has been applied to the handling of hazardous materials such as carcinogenic compounds.

- The major contributions to the development and application of neutral injection heating for fusion were made at ORNL. These include the development of the initial physics and technology, as well as a prime contribution to the initial applications and understanding of this important plasma heating technique (1969 to present). Devices were also developed at ORNL which, in conjunction with the Princeton Plasma Physics Laboratory, produced a 70 million degree plasma in the Princeton Large Torus (1978).

- A broad array of instrumentation and monitoring techniques for fossil-energy-related applications was developed that provides the basis for work area monitoring for industrial hygiene purposes of a broad class of carcinogenic polyaromatic hydrocarbons (PAH) which are produced in coal conversion reactions. The instruments include the derivative ultraviolet absorption spectrometer (DUVAS) for detection of specific gaseous organic emissions, the portable "spill spotter" for detection and quantification of work surface PAH contamination, the light-pipe luminoscope for detection of PAHs on skin, and a personnel monitor for determining individual worker exposure to volatile organics, including PAHs (1977 to present).

PACIFIC NORTHWEST LABORATORY

- The Pacific Northwest Laboratory (PNL) successfully demonstrated the immobilization of high-level waste from the nuclear fuel reprocessing of six commerical fuel assemblies in a stable glass form for storage (1976-1979). The process is being transferred to the Savannah River Laboratory for use in the Defense Waste Processing Facility. It will be used in the West Valley Demonstration Project to solidify the liquid high-level wastes stored in tanks at the site.

- For over 30 years the Laboratory has conducted experimental research that has lead to major improvements in nuclear power plant and core fuel performance, core life, plant safety, and plant factors. This research has included a cooperative program (1973-1975) with Japan and several European countries that led to resolution of fuel densification questions threatening shutdown of numerous nuclear power plants in the United States and throughout the world.

- The Laboratory established the technical, health, and environmental basis for the private-sector use of mixed oxide (plutonium and uranium) fuels in light water reactors (1960-1970). The studies have led to a technology base for a better understanding of the use of uranium oxide and mixed oxide fuels. The technology was adopted by one corporation as a new venture of providing mixed oxide and uranium oxide fuels that has grown to a multihundred million dollar fuel reload business with a billion dollar backlog (1967-1975). Also, critical mass data for plutonium, uranium, and mixtures of the two provided information used by industry to design nuclear fuel cycle facilities and equipment (1967 to present).

- Electropolishing and vibratory-finishing techniques for decontaminating metal surfaces were developed at PNL. These techniques are being used for the cleanup at Three Mile Island; they have been incorporated in mobile decontamination units operated by seven commercial companies; and they are factored into decontamination plans of most DOE sites (1975-1980).

- An advanced cooling-tower process that used little or no water was developed; this is an important alternative for arid Western states and other regions of uncertain future water supply. The concept is being demonstrated by the private sector at a utility power station and holds the potential of 30% to 40% cost reductions over existing dry-cooling technology (1974-1981).

- High-rate and large-volume sputtering processes have been developed for the versatile fabrication of special-purpose materials and coatings. The technique has been used for coating turbine blades for increased reliability, fabricating materials for high-energy-laser mirrors, and trapping krypton gas in metals in order to meet release criteria for nuclear reactors and other nuclear facilities (1969 to present).

- Experiments on effluents and products for coal conversion processes conducted for about six years suggest that mutagenic and probably carcinogenic effects of coal liquids are due to a relatively small faction of the constitutents of coal conversion liquids. Mutagenic effects are due to primary aromatic amines. Also, researchers found that coal liquids, because of their high phenol content, are more toxic to aquatic organisms than petroleum and petroleum-based fuels. Hydrotreatment of the coal liquefaction materials reduces these toxic constituents and is expected to ameliorate effects. Results are being used by industry to (1) develop alternative coal conversion processes that produce less phenol and fewer primary aromatic amines, (2) modify processes to remove these mutagenic and toxic constituents, and (3) assess potential environmental and health impacts of a commerical coal liquefaction industry (1976-1981).

- The Laboratory has developed a cationic asphalt emulsion that can be used to seal radon gas in piles of uranium tailings. The new emulsion forms a tight electrostatic bond with the soil rather than the usual mechanical bond. Results after six months of a field study with the new emulsion indicate a greater than 99.99% reduction in the amount of radon gas normally released from uncovered tailings (1978-1981).

- Health and environmental studies of radionuclides have been conducted at Hanford for over 30 years using Hanford-developed instruments and procedures for low concentration measurements. Health effects of transuranic (radioactive) elements were measured as a function body entry route, specific radiation compound, and animal species and ages. Possible synergistic and antagonistic effects of combined exposures to transuranic elements and

57-279 O - 87 - 54

PACIFIC NORTHWEST LABORATORY (Continued)

nonnuclear environmental contaminants were determined. Effects of environmental exposure routes and mechanisms of biological availability of transuranic elements were also ascertained. These data are widely used in setting or justifying existing radiation exposure standards and as a basis for resolving issues and making decisions. For example, results from studies of plutonium have clarified questions about potential health effects of plutonium and the issue of "hot particles"; and results from krypton inhalation studies supported that decision to vent krypton gas at Three Mile Island (1977-1981). The extreme measurement sensitivities resulting from the instrumentation developments and radioanalytical procedures have been used for meteorite and lunar sample analysis, exploitation of mineral resources, nuclear proliferation control, and categorization and characterization of pollutants from all phases of energy production.

- The Laboratory has been instrumental in developing siting and methodology criteria in support of major national programs. In the 1960s, extensive environmental studies were conducted at both Cape Canaveral, Florida, and Vandenberg Air Force Base, California, which established criteria for safety in expanding space programs, including that required for siting of launch facilities. In the early 1970s, the response to new legal requirements for environmental assessment of commercial nuclear facilities, measurement and analysis methods were established to determine the health and environmental impact from nuclear operations. Criteria and procedures developed by PNL for environmental impact statements of nuclear reactors were rapidly deployed and are still used by industry. More recently (1977-1981), siting criteria, realistic wind data, and measurement techniques have been developed that facilitate the use of modern large and small wind turbines in the continental United States. Specific uses of the PNL information and techniques by the private sector include: (1) screening potential sites for power production units; (2) improving site selection capabilities; (3) conducting market studies, economic analysis, and feasibility studies; and (4) diversifying their business to include wind measurements (1962-1981).

SANDIA LABORATORIES

Weapons

- Since its establishment in 1949, Sandia has developed safe, reliable, deliverable, field-ready weapons using the nuclear devices developed by LANL and LLNL. Sandia's weapons research and development includes arming, fuzing, and firing systems; command and control systems; and the structural and aerodynamic designs. Significant advances in safety, security, and flexibility of those systems as well as in miniaturization of components and protection against hostile environments have been made. Sandia has also been instrumental in extending component shelf life, thus greatly reducing stock-pile maintenance costs. The Laboratory performs these functions for all nuclear weapons in the stockpile. Until about 1973, Sandia's activities were 100% defense related; today about 75% of the staff is engaged in defense activities. Since defense work is classified, representative unclassified examples of accomplishment cannot be supplied except for the nonweapon projects started within the last five-ten years.

Nonweapons

- In a program initiated in the early 1970s, Sandia has discovered a family of transparent electroptic ferroelectric ceramics based on lead lanthanum zirconate titanate (PLZT) and has developed unique solid-state devices based on these materials. The applications include image storage, processing, and display devices; light valves and shutters (e.g., flashblinders and welding goggles, spectral and variable density filters); and numeric displays. Over 20 companies and laboratories in the United States and abroad now have active research and development programs on PLZT materials and devices.

- After conducting systems studies of fossil and geothermal processes, Sandia developed more than two dozen devices and processes now widely used by industry. Examples are high-temperature microcircuits, coring devices, new drilling muds, new hardrock drill bits, and a downhole combustion device for injecting steam into oil-bearing formations. Since about 80% of this country's heavy oil deposits will be recovered using thermal energy, it is significant that downhole steam generators use less fuel, create less pollution, and recover more oil from greater depths than surface generators. Several commercial firms are in design and manufacture of the device (1974-1982).

- Sandia has managed a significant fraction of the national solar energy program. The Laboratory's systems studies and experience with costs of hardware construction and operation revealed market limitations that were not commonly recognized nor publicized. Over 20,000 industrial and political decision makers have been extensively briefed on the results of this work (1972 to present).

- Sandia's Combustion Research Facility was opened in 1981. Already, experimental results and computer codes from the combustion research program have been used by the automotive industry to modify engine designs for greater fuel efficiency, and theoretical analyses have enabled oil and power systems to devise a technique for significantly reducing a major pollutant product of combustion.

- In 1975 a patent was granted on Sandia's Hot Gas Solder Leveler, which, relative to other solder levelers, reduced process time by 90%, pollution by 95%, and power requirements by 60%. Several firms have manufactured the hundreds of Hot Gas Solder Levelers in use domestically and overseas; annual sales estimates are in the neighborhood of $20 million.

- Since the concept of using laminar airflow to create ultraclean and contamination-free environments was developed at Sandia in the early 1960s, numerous manufacturers have produced many thousands of clean rooms and work stations for medical, industrial, and other applications. Annual sales in the United States are estimated to exceed $100 million.

- Sandia has identified and developed understanding of very important long-term, low-level radiation damage dose-rate in polymeric materials used in nuclear power reactors (1978 to present). This work, which grew out of extensive radiation effects research, has resulted in the worldwide reexamination and rewriting of test methodology for qualification of materials used in nuclear power reactors.

- Experimental and analytical data that reduce the uncertainties in understanding several accidents in commercial nuclear power rectors have been developed here. The program uses Sandia's unique Annular Core Research Reactor (ACRR) as well as other specialized materials test

SANDIA LABORATORIES (Continued)

facilities. This program has shown several hypotheses used in designing for future reactors to be incorrect. Also, the ACRR has allowed reactor safety experiments that produce more accurate assessments of reactor safety (1975 to present).

- Sandia has developed the technology for radiation-tolerant large-scale integrated circuits and transferred this technology to industry. Radiation-hardened microelectronics applications include national security, nuclear reactor instrumentation, satellite based equipment, and the U.S. space program.
- New concepts and techniques in modular pulsed power, power conditioning, and power concentration that are leading to particle accelerators and similar devices capable of delivering extremely high energies and powers have been developed. These devices are finding important applications in studies of high-energy-density plasmas, the effects of intense radiation on materials, and directed-energy particle beams (1972 to present).

APPENDIX 6

NASA
1986 Long-Range Program Plan

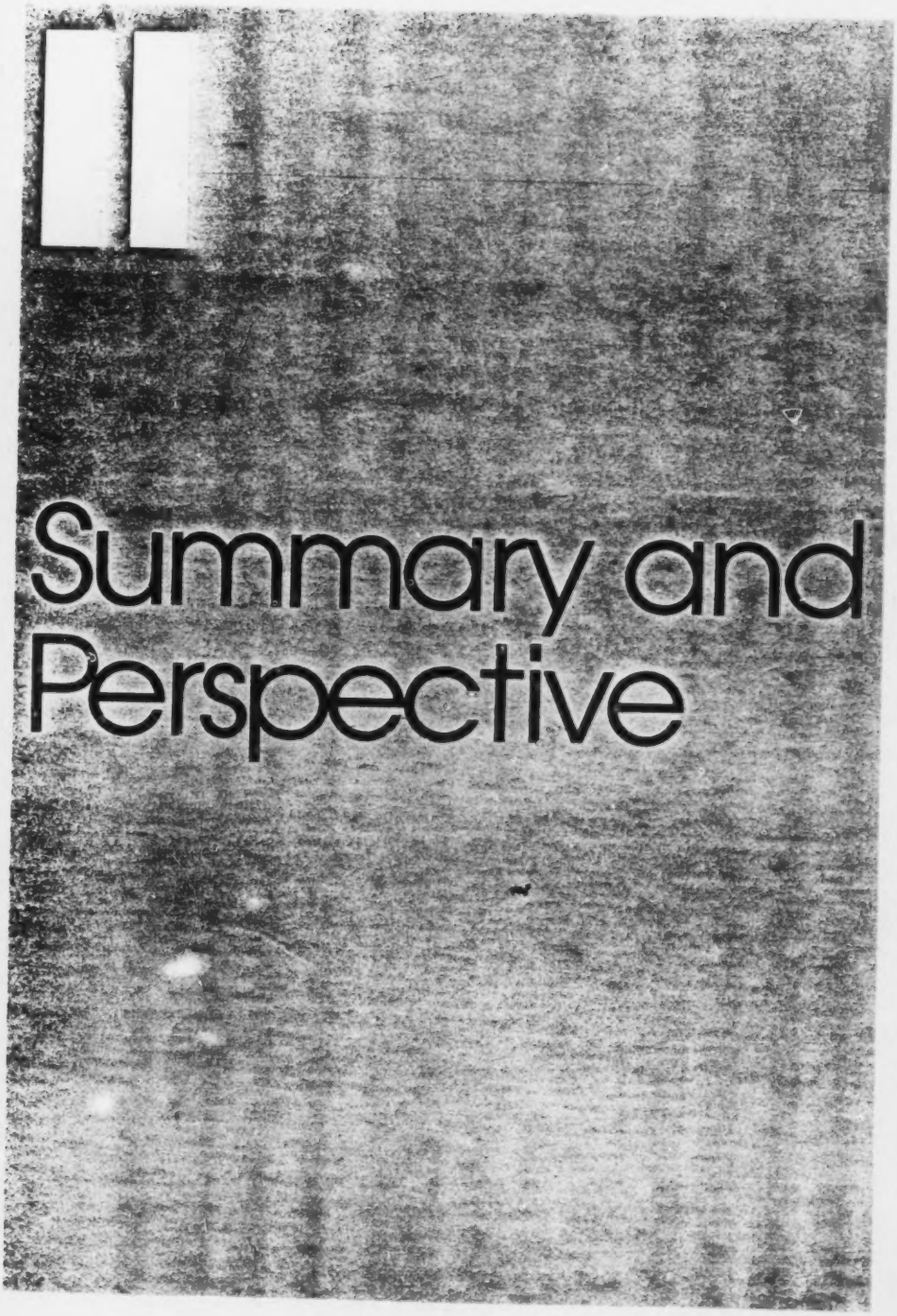
Compiled by

Management Support Division
Office of External Relations

August 1985

NASA
National Aeronautics and
Space Administration

Washington D.C.
20546


Summary and
Perspective

II. SUMMARY AND PERSPECTIVE

CONTENTS

A. Mission, Goals, and Objectives....1
B. Space Program Highlights to Year 2000....4
1. Space Science and Applications....4
a. Study of the Distant Universe....4
b. Exploration of the Near Universe....5
c. Earth and Its Environment....7
d. Life Sciences....8
e. Satellite Communications....9
f. Microgravity Science and Applications....10
2. Space Flight....11
3. Space Station....13
4. Space Tracking and Data Systems....15
a. Space Network....15
b. Ground Networks....15
c. Communications and Data Systems....16
d. Research and Development for Advanced Systems....16
e. Advanced Studies....16
5. Space Research and Technology....16
C. A Vision of the Space Era Beyond the Year 2000....18
1. Space Infrastructure by the Year 2000....18
2. Space Programs of the Early 21st Century....19
a. Earth Observations and the Near-Space Environment....20
b. Solar System Exploration....20
c. Astrophysics and Solar Studies....21
d. Life Sciences....22
e. Materials Processing....22
f. Communications....23
D. Aeronautics Program Highlights to Year 2000....23
E. Aeronautics Beyond the Year 2000....26
1. Supersonic Cruise....27
2. High-Speed Rotorcraft....28
3. Short-Haul Transports....28
4. Hypersonic Flight....29
5. Research Opportunities....29
F. Institution....30

II. SUMMARY AND PERSPECTIVE

A. Mission, Goals, and Objectives

The Reagan Administration assumed office in January 1981 committed to maintaining U.S. leadership in aeronautics and space. Toward that objective, it gave top priority to completing development of NASA's Space Shuttle and, with the Shuttle as the core element, to achieving full operational status for the Space Transportation System as an economically profitable and productive national resource. Advancement of those and other NASA space programs has benefited the economy and, at the same time, confirmed NASA's status as a world leader in science and technology. Space exploration has been and continues to be a catalyst for national progress and achievement.

The direction of NASA's mission and activities in space continues to reflect national policy and purpose as stated in the National Aeronautics and Space Act of 1958, as amended. A landmark achievement of the U.S. political system, that act directs NASA to explore space for peaceful purposes for the benefit of all mankind and to cooperate with other nations or groups of nations in pursuit of the Act's objectives. The President reaffirmed that commitment in his State of the Union address to Congress on January 25, 1984. He presented "four great goals to keep America free and secure in the eighties": "to ensure steady economic growth," "to build on America's pioneer spirit and develop our next frontier--space," "strengthening our community of shared values," and "a lasting and meaningful peace."

On August 15, 1984, the President approved a National Space Strategy designed to implement the national policy for space, as amended by Congress and as supplemented by his State of the Union address. The provisions of that strategy applicable to the civil space program are to:

- Insure routine, cost-effective access to space with the Space Transportation System
- Establish a permanently manned presence in space
- Foster increased international cooperation in civil space activities
- Identify major long-range national goals for the civil space program
- Insure a vigorous and balanced program of civil scientific research and exploration in space
- Encourage commercial Expendable Launch Vehicle activities
- Stimulate private sector commercial space activities.

Development of the space frontier, the President's second goal, will affect, and contribute to achievement of, his other three goals; and the major new element in his strategy that will help to ensure meeting that goal is establishment of a permanently manned presence in space. Permanent manned presence in space will enable the Nation, he said, "to follow our dreams to

distant stars, living and working in space for peaceful, economic and scientific gain." The NASA program initiated to establish that permanent presence is the Space Station.

As currently perceived by NASA engineers and scientists, the Space Station will be evolutionary in concept and design to accommodate addition, modification, and in future decades, replication. It is to be a multipurpose facility in Earth orbit, permanently occupied by humans. A national research laboratory for both government and industry, it will serve, as well, as a repair and assembly station for satellites and space payloads. As it evolves, it ultimately will serve as a base for new operations and initiatives in space and, most important, will be valuable for the creation of new technologies and industries. Such a facility in full operation, the President pointed out, has "enormous potential for commerce." Research in space is expected to yield new products leading to new businesses. In addition, development and production of the Space Station will be a boost to the economy; and the new skills, advanced knowledge, and technology that result will be used in other areas of industry. Each new step in achieving aerospace goals has added new dimensions of excellence to industrial capabilities; and if past is prologue, this great enhancement of space capabilities certainly will contribute to economic growth.

Pioneering in space by building a permanent settlement in that vast frontier also has meaning with respect to the President's third and fourth goals: "strengthening our community of shared values" and "a lasting and meaningful peace." A community in space, with U.S. personnel working and functioning there, will reflect the shared values of a democracy in action for freedom and peace. The President intends the U.S. Space Station to be an instrument for peace. Other nations, he stated, will be invited to join the United States on the Station "so we can strengthen peace, build prosperity and expand freedom for all who share our goals."

Estimates are that the Space Station can be in orbit by the early 1990s, around the 500th anniversary year of America's discovery by Columbus. Now, as then, the discovery of a new frontier is prelude to its development. A new world emerged then; and mankind now may be on the threshold of building another new world or, at least, of extending Earth's limits into near space and beyond.

Support of the Space Station and of other anticipated activities will require definition, design, and acquisition of a second-generation space transportation system, including unmanned cargo vehicles and second-generation orbiters.

In extending Earth's limits, NASA has set for itself the following goals, each of which is in keeping with the mandates of the National Aeronautics and Space Act of 1958, as amended:

- Provide for our work force a creative environment and the best of facilities, support services, and management support so that they can perform with excellence NASA's research, development, mission, and operational responsibilities. Provide for the development of employees so as to enhance and sustain an integrated work force of highest quality at NASA.

- Make the Space Transportation System fully operational and cost effective in providing routine access to space for domestic and foreign, commercial, and Governmental users.

- Develop within a decade a permanenty manned Space Station.

- Conduct an effective and productive aeronautics research and development program which contributes materialiy to the enduring preeminence of U.S. civil and military aviation.

- Conduct an effective and productive Space and Earth Sciences Program which expands human knowledge of the Earth, its environment, the solar system, and the universe.

- Conduct effective and productive space applications and technology programs which contribute materially toward U.S. leadership and security.

- Expand opportunities for U.S. private sector investment and involvement in civil space and space-related activities.

- Establish NASA as a leader in the development and application of advanced technology and management practices which contribute to significant increases in both Agency and national productivity.

The Administration's proposed budget for NASA for FY 1986 supports those goals, including sufficient funding for some new initiatives. It reflects the President's commitment to establishing a permanently manned space station and recognizes the importance of research and development for the well-being of the national economy. Flight activity will continue to increase to accommodate not only NASA payloads, but also those of paying customers, with plans calling for 10 Shuttle flights in FY 1985, 14 in FY 1986, and continued increases through the end of the 1980s.

The principal activities provided for are as follows:

- Space Transportation--While moving forward on the Space Station program, top priority attention to achieving for the Space Transportation System the ability to fill space transportation needs through the 1980s and beyond

- Space Science and Applications--Continued progress on approved projects, initiation of such programs as Upper Atmosphere Research Satellite, and further technology development and ground test and flight test programs for the Advanced Communications Technology Satellite

- Space Research and Technology--Continued efforts in generic disciplinary base technology programs with modest expansion of system oriented efforts in platforms and Space Station technology, transportation systems, and spacecraft

- Aeronautical Research and Technology--Additional work in aeronautical disciplines such as aerodynamics, structures, materials, propulsion,

and controls to provide technology for totally new aircraft systems, including rotorcraft, high performance and subsonic aircraft, and advanced propulsion systems

- The Institution--Maintenance and improvement of NASA's professional work force of scientists, engineers, and technicians to ensure efficent, effective, and innovative progress in fulfilling program objectives.

B. Space Program Highlights to Year 2000

The subsections of this chapter that follow present the highlights of the programs NASA plans to conduct in the remaining years of the 20th century, including the programs' goals, objectives, and major new initiatives planned for the 10-year period beginning in FY 1986. Each program is described in greater detail in chapters III through IX of this report.

1. Space Science and Applications

The Space Science and Applications program is responsible for most of the Nation's scientific research in space and for exploring ways in which space can be used in practical applications by industry, in the life sciences, and in maintaining Earth's natural resources. It includes observations and studies of the distant universe and of the fundamental physical laws important to understanding the distant universe, exploration of the near universe, and efforts to understand more about Earth's planetary features and environment. Its applications programs include research in the life sciences to enable humans to function and work in space, experiments in materials processing in the microgravity of space, and expansion and improvement of such services as satellite communications.

Summaries of the six major areas of endeavor in space science and applications follow. Each area is described in greater detail in chapter III.

a. Study of the Distant Universe

As a result of NASA's program in space astronomy and astrophysics during the past two decades, a new view of the universe is emerging; and new discoveries are being made at an astonishing rate. Rocket and satellite observations at ultraviolet wavelengths reveal the ejection by many types of stars of enormous amounts of material at high velocities. A revolution is occurring in knowledge of the chemical composition and physical state of interstellar gas and dust. Entirely new types of celestial objects are being discovered. Explosive events of unimaginable violence that occur routinely in the universe are being observed. Studies of the sun, fundamental to interpreting the distant universe, may provide the first look into that star's interior. For assurance that this revolution in understanding of the universe will continue at the same rapid pace, new observing capabilities are planned.

In the current Astrophysics program, several research missions are providing diverse information and measurements on the nature of the universe. While each mission has a particular objective, the data it acquires may often be augmented substantially by data from one or more

other missions. For example, the objective of the Solar Maximum Mission is to observe solar flares, but data from several other missions add to understanding of flares on the sun and other stars.

The International Ultraviolet Explorer supplements the Solar Maximum Mission. The Space Telescope, scheduled for launch in 1986, is the first major astronomical observatory designed and built to be serviced and upgraded in orbit. It is planned to be in operation for two decades and will be able to make observations in the ultraviolet, visible, and infrared regions of the spectrum. The Infrared Astronomy Satellite was launched in 1983 in cooperation with the Netherlands and the United Kingdom. Analysis of its data continues to provide new discoveries in infrared astronomy. Under development and to be launched within this decade are the Roentgen Satellite, a cooperative program with the Federal Republic of Germany to investigate many phenomena discovered by the second High Energy Astronomy Observatory; the Gamma Ray Observatory, to investigate the highest energy reaches of the electromagnetic spectrum; the Cosmic Background Explorer, to measure precisely the spectral and directional distribution of cosmic microwave background radiation; and the Heavy Nuclei Collector, to detect charged particles such as the rare, heavy nuclei of uranium. The program also includes extensive theoretical and laboratory research and investigations to be flown on Spacelab.

The major initiative to be begun through FY 1990 is the Advanced X-Ray Astrophysics Facility, which will advance x-ray astronomy into the mature observatory stage. It will be as significant an advance in x-ray astronomy as the Space Telescope will be in optical astronomy. Other initiatives planned for the FY 1986 through FY 1990 period are principally investigations of the structure of space and time, the structure of the sun, the life cycle of stars and galaxies, and interstellar space. They include Gravity Probe-B, Space Infrared Telescope Facility, Solar Seismology Mission, Extreme Ultraviolet Explorer, X-Ray Timing Explorer, Far Ultraviolet Spectroscopy Explorer, Solar Corona Diagnostics Mission, and several Spacelab investigations.

In the period between FY 1991 and FY 1995, two mature observatories will enter development. The Advanced Solar Observatory will make coordinated observations of all aspects of the surface of the sun to study the evolution of solar features and observe events that are especially revealing. The Large Deployable Reflector will investigate the processes of birth of celestial bodies. Other planned initiatives are the High Throughput Mission, Very Long Baseline Radio Interferometry, and Starprobe. The Space Station will service those observatories during this "golden age" of astronomy.

b. Exploration of the Near Universe

The near universe includes all bodies in the solar system except the sun and Earth. Exploration of the near universe is vital to a full understanding of the relationship of Earth to the sun and other members of the solar system. Specific goals of the program are to understand the origin, evolution, and present state of the solar system; Earth through comparative planetary studies; and the relationship between the chemical and physical evolution of the solar system and the appearance of life.

In the years since the first flyby of Venus, planetary exploration has experienced a golden age. It has brought new knowledge and established U.S. leadership in this area of space science. U.S. spacecraft were the first to visit Mercury, Venus, and Mars. Only U.S. spacecraft have crossed the asteroid belt into the outer solar system; and only a U.S. spacecraft, Pioneer 10, has exited the solar system. All told, over two dozen bodies--planets and their satellites--have been explored at close range; and the interplanetary medium has been partially characterized.

The current solar system exploration program consists of three parts: planetary research and analysis, development flight projects, and mission operations and data analysis. Research and analysis and mission operations and data analysis ensure program continuity toward exploration goals. Flight projects currently progressing are the Voyager 2 extended mission, which is headed for encounters with Uranus in 1986 and Neptune in 1989, and continued operation of Pioneer Venus, Pioneers 6 through 11, Voyager 1, and the International Cometary Explorer (the retargeted International Sun Earth Explorer-3), which is on its way to an encounter with the comet Giacobini-Zinner in 1985. Approved flight projects in the pre-launch development stage include the ASTRO payload planned for flight on the Shuttle to observe Halley's Comet during its 1986 flight through the solar system; Galileo (Jupiter orbiter and probe), which is a cooperative project with Germany; International Solar Polar Mission, which is a cooperative project with the European Space Agency; the Venus Radar Mapper, the first of the moderate-cost missions recommended by the NASA Advisory Council's Solar System Exploration Committee; and the Mars Observer, the first of the Planetary Observers, to be launched in 1990 to investigate that planet's atmosphere, surface geochemistry, interior, and climate on a global scale.

The Solar System Exploration Committee has recommended a core program containing 13 exploration missions, including the Venus Radar Mapper and the Mars Observer, to be undertaken by the year 2000. In support of that program, four new initiatives are planned for the next five years. They will establish firmly the exploratory phase of exploration in all regions of the solar system. The first is the Comet Rendezvous and Asteroid Flyby, scheduled for launch in 1990. Its purpose will be to investigate the physical and chemical state of comets. The second is the Lunar Geoscience Observer scheduled for launch in 1991 to assess lunar resources and to extend the Apollo program's science investigations to a global scale. The third is Cassini (Saturn Orbiter and Titan Probe), to be launched in 1993 to investigate Saturn and the largest of its satellites, Titan, especially Titan's unique, dense atmosphere. The fourth is the Coma Atmospheric & Elemental Sampling and Return mission, whose objective will be to obtain both intact and plasmatized samples of comet coma materials and return them to Earth for detailed analysis.

The Committee also has recommended addition of one or more intensive study missions during the 1990s as resources then available permit. The core program was formulated under the constraint that no new enabling technologies be required for implementation. In contrast, the augmentation initiatives will require significant new enabling or strongly enhancing technologies.

c. Earth and Its Environment

The view of Earth from space has engendered a growing realization that a full understanding of Earth and its environment requires a strong global research program spanning the scientific disciplines associated with study of the whole Earth, including atmospheric physics and chemistry, oceanography, geology, geophysics, and the emerging science of the biosphere, global biology. NASA's program to study Earth is global, interdisciplinary, and integrated, with emphasis on understanding processes that affect Earth's habitability, particularly its biological productivity and air and water quality. The program involves coordinated observational, theoretical, and experimental investigations and development of future observing technologies. Those activities are complementary and together form a balanced program of system and process studies. The program consists of elements that range from the most fundamental Earth sciences studies from space, to experiments demonstrating how data from space concerning Earth's resources and environment can be used to benefit society.

The Earth resources part of the program uses multispectral (visible and near-infrared), thermal-infrared, and active-microwave remote sensing systems to collect data for research and to demonstrate the utility of remote sensing in agriculture, land-use analysis and planning, hydrology, and geology. Landsat spacecraft have been the principal vehicles for Earth resources observation. Landsat 4, launched in July 1982, carried the Thematic Mapper sensor into orbit for the first time. That sensor has about twice the spectral resolution, three times the spatial resolution, and four times the sensitivity of the Multispectral Scanner sensor carried by earlier Landsat spacecraft. Landsat 4 technical problems curtailed the sensor's operation; but Landsat D', launched in 1984, carries another Thematic Mapper. The Shuttle Imaging Radar-A and other experiments on the Shuttle also have provided much valuable and useful information. The current program includes experiments with an improved imaging radar system, SIR-B, which was first flown on the Shuttle in 1984.

The objective of the atmospheric science program is to increase understanding of atmospheric processes and their effects on weather, climate, and the global environment. The current program of observations to further that understanding uses sounding rockets; balloons; aircraft; free-flying satellites, such as the Earth Radiation Budget Experiment launched in 1984; and Shuttle-borne instruments. Programs are in process to study global biology, Earth's plasma envelope and its interaction with the sun, geodynamics, trace species in the troposphere, and the oceans.

Earth science programs planned for initiation by FY 1990 include the following: Shuttle-Spacelab Payloads--to study the basic processes by which electromagnetic energy and particle beams interact with plasmas in the universe and to acquire information on the behavior with time of the solar constant, the solar spectrum, and the upper atmosphere; Ocean Color Imager--to provide synoptic global measurements of chlorophyll concentration as a primary data base to which complementary ship, airplane, and buoy data can be added to yield primary productivity estimates of high accuracy for key oceanic regions; Tethered Satellite System--to develop with Italy a system to conduct Earth science and applications experiments in regions remote from the Shuttle; Topography Experiment for Ocean

Circulation--to improve significantly capabilities for observing the oceans on a global basis; Magnetic Field Satellite--to test results derived from Magsat-1 data and provide an updated survey for the 1990 reference field; Geopotential Research Mission--to provide the most accurate models yet available of the global gravity field, geoid, and crustal magnetic anomalies; and International Solar Terrestrial Physics Program--to attempt, for the first time, a quantitative study of the complete solar-geospace system.

Studies of Earth in the 1990s will focus on long-term physical, chemical, and biological trends and changes in the environment. They will assess the effects of natural and human activities and provide improved models for estimating the future effects of humans and other species on Earth's biological productivity and habitability. They will be interdisciplinary and require sophisticated supporting technologies, particularly for long-term data management.

d. Life Sciences

The Life Sciences program has two goals: to understand how life forms are affected by the environmental conditions they encounter in space and to find how life originated and evolved in the universe. Life in the universe is studied by basic research programs in exobiology--which considers the origin, evolution, and distribution of life and its chemical precursors, and in biospherics--which studies how biological processes interact with the global environment. The effects of space flight on humans are investigated in the biomedical research program, and a complementary gravitational biology program deals with effects on other life forms. All four of these programs pursue their objectives through combined ground-based research and experiments in space.

Applied work in the life sciences has the objectives of ensuring the health of spacecraft crews and of improving technology to support life and work in space. A medical program has been evolved to test operational countermeasures to mitigate undesirable effects of space flight and techniques for treating illness and injury in flight. Projects are conducted to develop technology for instrumentation, closed life support systems, spacecraft habitability, and simulation of human capabilities.

The current program includes extensive study of problems associated with maintaining the health and productivity of spacecraft crews, emphasizing particularly the Space Adaptation Syndrome that affects some crew members during the first few days of a mission, but also maintaining continuing emphasis on questions of cardiovascular deconditioning, bone demineralization, and other effects of long-term space flight. Also under study are the origin, evolution, and distribution of life and life-related molecules on Earth and elsewhere as part of the evolution of the cosmos; the effects of biological processes on global dynamics, including the atmosphere, oceans, and terrestrial ecosystems; and the effects of differing levels of gravitational force on Earth life forms. Both ground-based research and an extensive flight-experiment program are employed. These programs will be continued and augmented in the years ahead to ensure that the Life Sciences program's goals will be met. The activities associated both with the medical effects of space flight on

humans and with gravitational biology will be involved closely with the Space Station program through the next 15 years. The Space Station's operating plans call for flying a medically diverse population of government and private individuals routinely for periods as long as the longest Skylab mission, and also for unprecedented amounts of extravehicular activity. Although the health problems that will occur should not be serious, it will be necessary to compile data on what does happen to the individuals and to verify countermeasures and treatment methods.

The Space Station will be a permanent laboratory where medical and biological studies can last as long as necessary to understand fundamental questions and resolve uncertainties surrounding longer flights. During the 1990s, the Life Sciences program will investigate the physiological and environmental factors that set limits on the ultimate duration of flights with human crews. Also, basic research will be performed to identify specific mechanisms of gravity perception in plants and animals and to show how gravity affects the development of organisms. Technology programs will develop improved countermeasures, methods for definitive care of ill and injured patients, and life support systems that regenerate food as well as air and water for spacecraft crews.

A phased program in biospheric research, planned to begin in the 1980s and to continue through the 1990s, will use Space Station unmanned platforms carrying Earth-looking instruments. Its goal will be to acquire data for a comprehensive model of global biogeochemical processes, which will constitute a key element in understanding Earth as a system. The search for life will continue with expansion of data acquisition and processing capabilities for the Search for Extraterrestrial Intelligence program, and of the use of Space Station payloads to capture extraterrestrial dust and to analyze the organic material content of the dust.

e. Satellite Communications

NASA's role in developing technology for satellites and other components of space communications has been and continues to be one of providing leadership in support of the private sector communication satellite marketplace, flight testing communications satellite advanced technology involving risk beyond that which private companies are able to accept, and supporting government use of space in non-military communications projects.

NASA's Communications program is facing a new challenge in both the private and public sectors. Within only two decades of the launch of the commercial communications satellite, SYNCOM II, the orbital arc is approaching saturation, requiring NASA to develop new technologies involving beam-hopping antennas and on-board switching for new satellites that will make more efficient use of the orbital arc. In connection with public sector communications, the Space Station program requires development of technology for satellite-to-satellite links, giant antennas that can be assembled and tested in space, and geostationary platforms.

NASA's current program, developed with industry's help, consists of the following major activities:

- o Basic research and technology development to provide a technology base for all of NASA's communications programs, performed cooperatively by NASA, universities, and U.S. industry

- o Technical consultation and support services to ensure growth of existing satellite services and their incorporation into new satellite applications

- o Advanced technology development to provide new and expanded satellite services and experiment coordination, primarily in the public sector

- o Satellite-aided search and rescue, a cooperative program in which Canada, France, the Soviet Union, and the United States are developing and demonstrating a satellite system for detecting and locating the position of signals transmitted automatically from aircraft, ships, and individuals in distress

- o Development and flight test of the Advanced Communications Technology Satellite to investigate electronically-hopped antenna beam communications, on-board switching, spectrum conservation, and K_a-band circuits

- o Development, in cooperation with U.S. industry and the Federal Communications Commission, of technology and system architecture for a satellite system with large antennas to provide a communications capability to mobile users on Earth; and flight testing of the system in the 1990s

Possible major initiatives for the Communications program include the following:

- o Study and advanced development of communications for the Space Station complex, including tests of 30 GHz, 60 GHz, and optical frequency high and low data rate links (The links also may involve the Advanced Communications Technology Satellite, the Shuttle, and a dedicated Spartan free flyer.)

- o Development of an antenna assembly and test range, collocated with the Space Station, for testing satellites, antennas, and payloads before their commitment to flight or transfer to geostationary orbit

- o Development of giant antennas for use about 1998 by both scientific and commercial platforms assembled at the Space Station and then transferred to geostationary orbit.

f. Microgravity Science and Applications

The strong multidisciplinary base NASA has established in space materials science will be developed further through a vigorous flight program conducted with the cooperation of industry. The goals sought are to investigate the behavior of fluids and the effects on that behavior of

carrying out processes in the microgravity environment of space, to provide a better understanding of the effects and limitations imposed by gravity on processes carried out on Earth, and to evolve processes that exploit the unique character of the microgravity environment of space to produce results that cannot be obtained in unit gravity.

The current program consists of ground-based investigations, experiments in space on the Shuttle's mid-deck, and experiments in the Materials Experiment Assembly. Some of the ground-based investigations that promise valuable results are studies of the effects of convection in the growth of crystals, phase separation mechanisms other than gravity, containerless processing, and bioseparation processes. The two principal Shuttle mid-deck experiments that have yielded interesting results and are expected to be developed further are the Monodisperse Latex Reactor and Continuous Flow Electrophoresis. The Materials Experiment Assembly is a carrier for materials processing experiments that fills the experiments' support needs independent of the Shuttle's systems. Experiments that have been conducted in it include isothermal and gradient processing in general purpose furnaces, processing of monotectic alloys, growth of crystals from vapors, and processing in an acoustic levitator furnace.

The emphasis of the program during the next several years will be on crystal growth of electronic materials, solidification of alloys and composites, containerless melting and solidification, containerless formation of glass, separation processes, fluid and transport phenomena, and combustion processes in microgravity. Another important activity is development of materials research facilities and apparatus. Present emphasis is on Shuttle mid-deck facilities and apparatus that potentially can be upgraded to fly in the cargo bay or Spacelab and, later, on the space station.

Two functions of the Microgravity Science and Applications program will have a substantial effect on the possibilities for the program's commercialization: the use of space to obtain knowledge that can be applied to improve terrestrial processes and the processing of materials in space to take advantage of the weightless conditions there. For the near future, materials processing in space will be restricted to small quantities of high-value, low-volume materials such as pharmaceutical products, electronic materials, optical fibers, highly specialized alloys, and possibly precision latex microspheres. NASA will continue to conduct, with industry participation, a vigorous flight program to foster future ventures by industry that will be of optimum benefit with regard to both the materials produced and the economics of production. NASA sponsors, and encourages others to sponsor, materials processing research, but leaves to industry the task of deciding whether commercial production is feasible.

2. Space Flight

The Space Flight program supports NASA's goals for space transportation and a permanent presence in space. Its early goals are to develop the Space Transportation System further and achieve routine, economical operations with it. Planned programs emphasize development of follow-on systems for space transportation and other large space systems, including the Space Station,

orbital platforms and facilities, and the test, transportation, and servicing systems required to support them.

The program's objectives for the FY 1986 through 1990 period are to:

- o Complete development, acquisition, and upgrading to its full capability of the Space Transportation System, and achieve routine operations with it by 1988
- o Encourage use of the Space Transportation System by domestic and international commercial customers
- o Carry out a total of 30 Shuttle missions in FY 1985 and FY 1986
- o Develop by the second quarter of FY 1986 a cost-effective Centaur upper stage compatible with the Shuttle
- o Support and encourage commercial development of upper stages
- o Develop a tethered satellite system
- o Continue demonstration of the abilities of the Shuttle for servicing satellites
- o Develop by 1990 an Orbital Maneuvering Vehicle for use in conjunction with the Shuttle and, later, the Space Station.

The program's objectives beyond 1990 are to:

- o Maintain a Shuttle launch schedule with reserve capacity, while conducting safe, successful Shuttle missions having progressively lower operational costs and shorter turn-around times
- o Help in meeting NASA's objective of developing and putting into routine operation in low Earth orbit by the early 1990s a manned permanent space station facility
- o Develop an orbital transfer vehicle complementary to the Space Shuttle for transportation of payloads to, between, and beyond Earth orbits
- o Define, design, and provide a second-generation space transportation system, including unmanned cargo vehicles and second-generation orbiters
- o Develop and operate on a routine basis, beginning in the mid 1990s, geosynchronous orbit space platforms that are unmanned, permanent, and multifunction
- o Develop and put into routine operation by the year 2000 geosynchronous orbit facilities that are permanent, multifunction, and able to be periodically manned
- o Develop technology and techniques to construct, deploy, or assemble such facilities in space, and to test and service them in orbit

- o Encourage and support NASA and industry development of technology to improve concepts for space boosters that significantly reduce launch costs.

The objectives associated with bringing the Space Transportation System to full operation will be achieved through completion of the current base-line program. Most Earth-to-orbit and all return-to-Earth transportation needs will be met by the Shuttle, supported by the discrete Shuttle Production and Capability Development program. That program is responsible for Shuttle and propulsion system production and residual development, launch and mission support, and system improvements. Current activities are focused on the Inertial Upper Stage and the Centaur modified for Shuttle use; achieving full flight status for Spacelab; increasing opportunities for Spacelab-based science and applications work; operational support services for the Shuttle and expendable launch vehicles; and procurement of expendable items for both launch systems.

Proposed new initiatives support both the nearer-term objectives of space transportation operations and the longer-term objective to establish a permanent presence in space. During the period of this plan, capabilities for providing orbital services will be demonstrated. System hardware development will follow the demonstrations. The results of those demonstrations and the Tethered Satellite System program will help determine the limits of orbital activities of both the Shuttle and the Space Station.

NASA's inhouse institutional base and system of industrial and other contractors required to achieve the goals of the Space Flight program will be maintained and strengthened.

3. Space Station

Establishment of a permanent manned presence in space is one of NASA's current eight goals and is a priority goal of the Administration as a means of maintaining U.S. leadership in space and of exploiting the economic and scientific benefits in that new frontier. Toward that goal, the President has committed to development of a space station by the early 1990s.

The program's near objectives have centered on identifying and synthesizing mission requirements for a civilian space station and reviewing a set of functional capabilities--the station's architecture. In addition, technology and advanced development programs are being initiated. To meet the goal of initial operation in the early 1990s, current plans include a 3-year definition phase and initiation, in FY 1987, of a design and development phase.

Because many aspects of the program will make it unique as compared with past space programs, the following program and management strategies have been established:

- o All major potential users of the Space Station, U.S. and foreign, will be involved from the beginning of planning activities to ensure that their needs are taken into consideration.

- Thorough project definition will be conducted before system development is undertaken.

- Involvement in the program will be agency wide and substantive. Overall direction of the program is the responsibilty of the recently established Office of Space Station in NASA Headquarters. Johnson Space Center has been designated "lead center," responsible for NASA-wide program management of design, system engineering and integration, advanced development and test, and customer interface. Johnson and other NASA centers are responsible for project management of the development (by contractors) of system elements.

- The station will be designed to accommodate evolutionary growth through incremental addition, modification, and replication.

- The station's elements will be maintainable and restorable in space.

- A rigorous design-to-cost approach will be followed to keep design and development costs within the $8 billion currently estimated. The program definition phase will fully explore the necessary tradeoffs.

- International participation in the program will be sought. Participation will be on a government-to-govennment basis and be designed to prevent unwarranted technology transfer.

- Although the Department of Defense has not yet identified current military requirements for a space station, NASA will keep the Department fully informed of Space Station activities.

- The Space Station will be designed to operate as autonomously as possible, except for resupply of materiel and personnel. A major objective of current planning is to define the optimum mix of human and machine functions.

During its existence from 1982 through 1984, the Space Station Task Force focused almost exclusively on mission requirements for the Space Station. Based on the results of contracted studies and workshops with wide participation of potential users, a preliminary set of phased Space Station missions for the period 1991 to 2000 was defined. The initial requirements included a manned element at 28.5^{o} orbital inclination, a platform at low inclination, and a platform in polar orbit. Although no approved configuration exists, the present reference configuration calls for functional capabilities corresponding to two habitat modules, a logistics module, two laboratory modules, an unmanned platform at orbital inclination of 28.5^{o}, an unmanned platform at orbital inclination of 90^{o}, an Orbital Manuevering Vehicle, and a servicing system.

The Space Station program currently is concentrating on selecting contractors for program definition and preliminary design (to extend through 1986) and on advancing critical subsystem technologies; encouraging further international cooperation and planning; completing focused studies on human productivity, automation and robotics, and data management systems; completing development of a separate acquisition plan for a technical and management

information system; and continuing the progressive updating of Space Station functional requirements.

A Space Station advanced development program has been planned to provide advanced technologies needed for an evolutionary station. It will be integrated with system definition activities, with a major milestone and decision point occurring at the end of the definition phase. Both ground-based and space-based test beds are planned and are expected to have a vital role in subsequent definition of evolutionary elements. They are expected to reduce the program's costs and risks.

4. Space Tracking and Data Systems

The Space Tracking and Data Systems program supports the Nation's missions in aeronautics and space by planning for, developing, and operating the space and ground network of tracking and data systems for missions of automated and manned orbital spacecraft, deep space vehicles, sounding rockets, balloons, and research aircraft. The program has four basic elements: space network, ground networks, communications and data systems, and development of advanced systems. Plans for those elements and for supporting mission activities follow.

a. Space Network

By 1986, tracking and data acquisition facilities for spacecraft in near Earth orbit will have evolved from a network of ground tracking stations around the world into a network of two Tracking and Data Relay Satellite System (TDRSS) satellites in geostationary orbit, an in-orbit spare, and a single ground terminal at White Sands, New Mexico, all owned and operated by a contractor. A network control center at Goddard Space Flight Center will control the system and manage network resources. The system will increase coverage of near Earth orbits from 15 percent to 85 percent.

b. Ground Networks

NASA will close nine more ground stations while phasing TDRSS into operation, leaving only six locations fully operational and consolidated under Jet Propulsion Laboratory management. The consolidated ground network will support deep-space missions and missions in high Earth and geostationary orbits. Early improvements planned for the network include arraying antennas to boost the signal received from the Voyager 2 spacecraft when it is close to the planet Uranus and nearly three billion kilometers from Earth in 1986; adding an X-band uplink command system to the ground network about 1987 to reduce the blackout effects of the solar corona on signals from Galileo and later planetary missions, to improve signal stability by a factor of five, and to improve ability to search for gravity waves; developing a capability at Dryden Flight Research Facility for supporting multiple missions; providing tracking and data acquisition support to the National Scientific Balloon Facility at Palestine, Texas; and improving the impact prediction system and fixed radar capabilities at Wallops Flight Facility.

c. Communications and Data Systems

To handle the substantial increase in data transfer and processing that TDRSS services will generate, greater use will be made of electronic data transfer and other automated features to reduce the need for human intervention and tape handling. Aged and obsolete computing systems for mission support will be replaced to increase reliability and reduce maintenance costs; and more use will be made of microprocessors to control dish-antenna operations. By 1986 a program-support communications network will be in operation to provide NASA and its contractors with supplemental communications service for conducting day-to-day business.

d. Research and Development for Advanced Systems

Though relatively small, the Advanced Systems program is a vital part of the total program, providing a base for future planning and for development of cost-effective support capabilities. Its objectives are to increase abilities for communicating with spacecraft, improve navigation capabilities, increase the operational capabilities of ground stations and data handling and processing networks, and develop technology to facilitate TDRSS use.

e. Advanced Studies

The TDRSS is expected to meet needs through most of the 1990s, but increases in data volume for missions planned after the 1990s will require new relay capabilities. More links and greater capacity will be needed. Studies already have examined some support needs and new technology that may satisfy them. Other studies are in process on technological problems related to a follow-on system for the TDRSS.

Rapid advances being made in telecommunications technology will have a profound effect on tracking and data acquisition support of deep space missions in the coming decades by making possible, for example, a deep space relay station. The program will continue to look ahead and make plans to meet such challenges.

5. Space Research and Technology

This program is responsible for conducting space research and technology to support the Nation's civil and defense space programs and overall economic growth. It is concerned with technology with broad applicability rather than that related directly to specific projects; and it concentrates on long-term, high-risk research and technology development to satisfy national space objectives. With commercial and military investments in the use of space growing rapidly, the program is focusing increasingly on national objectives and missions and addressing the technology needs of those other sectors more directly. Much of the work constituting the program is planned in consultation with the other NASA program offices, the Department of Defense, and industry. Much also is conducted jointly with them to facilitate transfer to them of the technology developed.

The following objectives form the basis for the program and related institutional plans:

- To ensure timely provision of new concepts and advanced technologies
- To support the development of NASA missions in space and the space activities of industry and other government agencies
- To utilize the strengths of universities in conducting the NASA Space Research and Technology program
- To maintain NASA's centers in positions of strength in critical space technology areas.

Those objectives will be realized, as the objectives of the Aeronautics Research and Technology program are, through a program of disciplinary research combined with a program of systems research and technology development; enhancement of the staff, facilities, and computational capabilities of the NASA centers; increased and more productive involvement of the universities; and greater emphasis on favorable transfer of technology. Also, NASA will use and make available for use by others its unique resource of space facilities to conduct research and technology development in the actual space environment.

The disciplinary research and the systems research and technology development both concentrate on maintaining excellence in five priority technical areas: large, flexible structures and their control; space power systems; launch vehicle and space propulsion systems; entry technologies; and space operations. The disciplinary research further concentrates on aerothermodynamics, materials and structures, information sciences, space data and communications, controls and guidance, human factors, space energy conversion, and propulsion. The systems research and technology development further concentrates on space transportation systems, spacecraft systems, and large space systems. The two programs have common technology objectives that provide a basis for decisions on funding, personnel, and facilities. Those objectives are for materials and concepts for thermal protection; longer-life, reusable engines; propulsion and aerobraking for the Orbital Transfer Vehicle; high-capacity electrical power generation, storage, and distribution systems; satellite communications; large antenna systems; space teleoperation, robotics, and autonomous systems; space information management systems; computer science for aerospace applications; computational aerothermodynamic techniques for entry bodies and rocket engines; human capabilities in space; concepts for advanced sensors; and distributed, adaptive controls for large space systems.

Augmentation in FY 1986 is planned for the automation and robotics program, to provide technology to increase the capabilities of systems and the productivity of humans in space; the large space structures program, to provide technology for the control of large flexible structures in space; and the Orbital Transfer Vehicle program, to develop technologies for a space-based, reusable Orbital Transfer Vehicle. Augmentation planned for later years include increases for Orbital Transfer Vehicle technologies, automation and robotics, in-space experiments, enabling technologies, entry research vehicles, a liquid oxygen-hydrocarbon research engine, Mars sample return technologies, and lunar base technologies.

C. A Vision of the Space Era Beyond the Year 2000

Most of the programs described in this report of NASA planning will reach fruition by the end of the 20th century. With the beginning of the next century only 15 years away, it is none too soon to begin preliminary planning of possible systems, programs, and activities for the early years of the 21st century. Detailed planning would be premature, but a range of studies of possible alternative programs must be conducted to help set goals and objectives for that period, to identify programs providing the greatest potential, and to identify technologies that need to be pursued. The results of many such preliminary studies conducted in the past 20 years and others now under way have contributed to the material sketched below.

1. Space Infrastructure by the Year 2000

With the Administration's recent commitment to development of a permanently manned space station to be in orbit in the early 1990s, a significant orbital infrastructure should be in place by the year 2000 to support programs in science and exploration, development of technologies and their application to improve life on Earth, and a wide range of commercial activities. By the end of the present century, the permanently manned Space Station and associated unmanned platforms will have had some years of operation in low Earth orbit conducting many of those activities. Other supporting systems will have been developed, or will be within NASA's capability to provide. They will have the ability to support large, permanent facilities for science, research and development, commerce, and other activities in low Earth orbit and geosynchronous Earth orbit; to provide routine, economical, flexible access to other orbits by manned and robotic systems; to institute routine check-out, refueling, repairing, and upgrading of space facilities, as well as removal of Earth-orbital debris; and to devise and implement uses and missions for the Space Transportation System such as large tethered systems for power generation, nonpropulsive transportation, and satellite constellations.

A cryogenic version of the Orbital Transfer Vehicle evolutionary family, currently in early stages of preliminary design, is expected to provide by the year 2000 reusability for manned sortie flights to at least geosynchronous orbit. It also should be able to provide the basis for transportation for longer flights to establish a lunar base and for planetary missions such as a Mars sample return. Supplemented at times by a remotely controlled Orbital Maneuvering Vehicle with special kits for remote servicing, fueling, and debris capture, it probably should be able to fly with or without crews with minimum change. Because it appears that servicing, maintaining, and refueling those reusable vehicles will be more advantageously accomplished in orbit than on the ground, the Space Station must be equipped with suitable hangar, servicing, and refueling facilities.

A potential need exists for routine flights of unmanned, cargo carrying, Earth to low orbit vehicles that, compared with the Space Shuttle, will have the ability to accept payloads with larger diameters and to lift greater weights. Those Shuttle-derived launch vehicles would be available, of course, for the payloads of other users.

Various advanced systems, tools, and techniques will have to be available by the year 2000 for routine servicing operations in the space regimes

occupied by satellites and other spacecraft. Also, substantial augmentations to crew and life support systems will have to be developed. Those augmentations must provide closed-cycle, regenerative water and air loops for onboard environment control and life support systems; regenerable, space-maintained, life support backpack systems for extravehicular activity; high-productivity mobility systems; Earth-norm food, hygiene, and habitability; and onboard automation that is able to handle tasks that do not necessarily require continuous manned attendance and that is flexible enough to allow easy upgrading as technologies advance rapidly.

2. Space Programs of the Early 21st Century

For the United States to exercise leadership in space and to improve the well-being of humankind on Earth and in space beyond the year 2000, long-range goals will be required for advancing scientific knowledge, space exploration, Earth applications, and commercial uses. Those goals will be set by the Administration and Congress after consideration by many individuals and organizations, the National Commission on Space, NASA, and other groups involved in the U.S. space program. Sustained space research and development also will be necessary to conceive and develop even more advanced innovative systems and techniques than those that have been developed or will be developed by the end of this century. Concepts exist for major manned and automated space missions for achieving those goals and for providing unprecedented scientific and technical benefits. Those missions will use all regimes of space accessible in the early 21st century: low Earth orbit; higher energy Earth orbits, including geostationary orbit; lunar orbit; the lunar surface; and the environs of the inner planets.

Achievements in the early 21st century in science, exploration, Earth applications, and commercial uses will depend on two trends: first, the increasing capabilities of space systems with regard to accessibility, payloads, stay times, and variety and sophistication of operations and, second, the increasing capabilities of instruments with regard to detection, resolution, pointing accuracy, and data collection and management made possible partly by improvement of their power supplies and cooling mechanisms. Those trends and the space infrastructure they produce, such as the Space Station, will support scientific, technical, and commercial activities and systems not now possible, including:

- Large facility-class observatory instruments in both low Earth orbit and geosynchronous Earth orbit
- Orbital platforms, both equatorial and polar and both automated and human-tended, carrying instrument payloads that are modular, variable, serviceable, and interchangeable
- Large facilities such as telescope mirrors and radio antennas assembled in space by humans for both scientific and communications purposes
- Routine use of the lunar surface for planetary geoscience studies, solar monitoring, astronomical surveys, and possibly extraction of resources

- Routine materials processing in microgravity, at bench-test through pilot-plant levels, probably with extensive commercial involvement and continual increases in the variety and quantities of materials produced profitably on a commercial basis

- Significant increases in the number of humans present in space, in various Earth orbits and possibly on the lunar surface

- Large-payload, high-performance planetary exploration missions made possible by clustering launch stages or by using Orbital Transfer Vehicle derivatives

- Planetary science networks and other long-term activities on other celestial bodies such as the moon, Mars, and asteroids.

a. Earth Observations and the Near-Space Environment

NASA's activities in the 21st century will use the Space Station and its platforms to emphasize synoptic, continuous, and long-term observations of Earth and its immediate surroundings from both polar and equatorial low Earth orbits. A wide variety of multispectral, microwave, and other forms of sensors will provide critical global information about Earth's land surfaces, atmosphere, and ocean systems. A complementary system of sensors will collect data on the near-Earth space environment and its dynamic behavior by monitoring the sun, sampling and analyzing the solar wind, detecting solar flare particles, and studying Earth's magnetosphere and its interactions with solar activity.

As space transportation capabilities increase, similar platforms in geostationary orbit will provide continuous monitoring of larger areas of Earth. Also, automated or human-tended instruments located on the lunar surface will begin complementary observations. That location will permit observation of Earth's entire face, with simultaneous investigation of Earth's space environment and magnetotail.

The complexity of the scientific problems involved in studying Earth and its space environment, the variety of observations possible, and the potentially high rates of data collection will require major advances in ground-based data collection, management, and analysis and in modeling and prediction techniques. Also, mechanisms will have been developed for the creation and management of large, integrated, interdisciplinary projects like the current Global Habitability study.

b. Solar System Exploration

Exploration of the solar system will be carried out in several ways, using a variety of space capabilities. Even by the beginning of the 21st century, many relatively small, cost-effective missions contained in the Solar System Exploration Committee's recommended core program will remain to be conducted. They can be carried out with the Shuttle-Centaur combination, an equivalent transportation system as a straightforward continuation of NASA's 1980s and 1990s program, or new transportation systems utilizing the Space Station's facilities. Some more demanding

missions, such as the return to Earth of samples from Mars or a comet, can be carried out in a similar fashion.

Instruments, chiefly telescopes, for planetary studies will be mounted on and supported by the Space Station and its associated platforms. Even more significant, perhaps, the Space Station's fueling and launching capabilities and the availability of launch stages with higher performance will permit automated missions to planetary systems that now are not easily accessible. Examples of those missions are a Mercury orbiter, a Neptune orbiter and probe, intensive study of the Jupiter and Saturn systems, and sample return missions of greater sophistication.

Routine access to the lunar surface will make possible the first intensive, systematic study of another major celestial body. Extensive sample collection and scientific traverses conducted by humans and long-term instrument networks installed and managed by humans will help determine the details of the moon's structure, composition, and history. They also will make accessible the record of solar and cosmic ray particle fluxes preserved in the lunar soil. Similar scientific activities can be carried out on Mars, either by large, automated spacecraft or by a manned mission. Other scientific achievements will include orbital remote sensing of that planet and a rendezvous mission to its moons Phobos and Deimos to emplace instruments on and return samples from them.

c. Astrophysics and Solar Studies

Studies of the universe beyond the solar system will continue to depend on the Shuttle or its equivalent to place into low Earth orbit a mixture of small specialized missions and large observatory-class facilities similar to those studied for the 1990s by the National Research Council's Astronomy Survey Committee. Those missions and facilities will be structured to attack specific problems that remain as the new century begins.

Automated and human-tended platforms in the Space Station system will use a variety of astronomical instruments to conduct a wide assortment of complementary activities. The ability of humans to assemble large structures in space will make possible space-based astronomical instruments not limited by the size and weight constraints of a Shuttle payload; for example, large optical and infrared mirrors and large antennas for radio astronomy. The Space Station also will make possible an exciting program of studies combining observations and spacecraft missions to investigate the sun as a star. The Space Station will support the larger and more sophisticated instruments needed for observing and monitoring the sun; and high-performance launch stages such as clustered Centaurs or Orbital Transfer Vehicle derivatives will make possible solar probes, grazers, and orbiters.

The lunar surface will become available as a platform for astronomical observations. Initial studies will be made with small, prototype, human-tended instruments and will emphasize sky surveys and the detection of unpredictable events like supernovas and gamma-ray bursts.

d. Life Sciences

The first quarter of the 21st century will see a major effort to develop protective systems and physiological countermeasures to qualify humans for space flight missions years in duration. A group of dedicated Space Station modules will provide space laboratory capabilities for this work. Among the most serious problems to be solved are bone demineralization, loss of muscle mass, and radiation protection. Concurrently, operations and life sciences studies in a lunar surface base can develop the information required to plan for human residence on other planets. Around the turn of the century, practical controlled ecological life support systems will enable human habitations to operate with little or no requirement for external supplies of crew support consumables. Therefore, the essential medical and biological requirements for manned missions to destinations far from Earth should be in hand by 2025.

Basic research on gravity effects in living organisms will become an established specialty within medical and biological science, building on the results of the 1990s.

The search for extraterrestrial life will be pursued through the use of large radio telescopes installed in space that will have improved signal analysis capabilities.

e. Materials Processing

Even before the end of this century, materials production in the microgravity of space should have become routine, probably with extensive commercial involvement, for such diverse items as pharmaceuticals, crystals, alloys, and special glasses. Evolution of the Space Station will allow that activity to expand, possibly to the pilot-plant level or beyond, into separate laboratory modules and human-tended laboratories in low Earth orbit.

A variety of space-based power systems, including solar photovoltaic, nuclear, and solar thermal systems, will be essential. They will supply power to the growing industrial complex associated with the Space Station and, perhaps, to facilities in geosynchronous orbit. The program for developing and testing solar power systems also can explore the feasibility of transmitting power to, for example, Earth's surface or the moon.

Access to the lunar surface will make possible the first routine use of extraterrestrial resources. Techniques could be developed to enable a lunar base, even before its permanent occupancy, to mine, extract, and fabricate products from lunar materials. The objectives will be to make the lunar base able to support itself as much as possible from lunar feedstocks and to foster the economic use of lunar resources elsewhere in space (for example, the use of lunar oxygen by space systems in low Earth orbit). Extraterrestrial resources also will be investigated by means of missions, manned or unmanned, to near-Earth asteroids to obtain information on and assess the availability of resources, especially the essential volatile elements carbon, hydrogen, and nitrogen, that are lacking on the moon.

f. Communications

Drastically expanded communications capabilities will be needed in the early 21st century to support both scientific and commercial activities in space. That need will be satisfied mainly by large (10- to 100-meter diameter) antennas--assembled and tended in space by humans at the Space Station and located at geosynchronous orbit. Initiation of long-term human activities on the moon will generate a high demand for communications that will require lunar communications systems consisting both of networks based on the moon's surface and of lunar satellites acting as relays. Satisfying those communications needs will require not only extensive research, but also development of new systems--such as large, space-based antenna arrays--and of space-based storage and assembly techniques. New techniques also will be needed for handling the voluminous communications traffic generated by both scientific and commercial activities.

The space capabilities available after the turn of the century will create a revolution in space research, exploration, and exploitation. The resulting research and operations environment will have a potential that can be imagined only dimly at this time because of the many factors affecting that environment: large payloads; long instrument lifetimes; human-supported space operations; and routine access to low and geosynchronous Earth orbits, the lunar surface, and possibly the Martian surface and, for unmanned missions, the entire solar system. The inevitability of human exploration--and eventually habitation--of the solar system will begin to be apparent, and possibilities for tapping the resources of the moon and the asteroids will become evident. Means developed before the turn of the century for effectively monitoring Earth's environment will help humankind manage that environment wisely for the benefit of all. Use of space for industrial processes and other commercial purposes should be commonplace. Consequently, the early 21st century should be an era of unparalleled achievement for humanity.

D. Aeronautics Program Highlights to Year 2000

Upon completion of the Aeronautics Policy Study in 1982 by the Office of Science and Technology Policy, the Administration declared as a national policy objective the "provision of a proven technology base to support the future development of superior U.S. aircraft." That policy is sustained and, indeed, reinforced by NASA's goal for its Aeronautics program for FY 1986 and beyond: to conduct research and technology development that ensures the enduring preeminence of U.S. aviation. That goal is supported by the following program objectives:

- Maintain the excellence of the NASA research centers in facilities, computational capability, and technical and professional staff. This objective requires repairing and replacing aging facilities as well as developing additions and improvements, advancing scientific and engineering computational instruments and programs, and enhancing staff competence by selecting personnel with highest abilities and providing them with career incentives.

- Conduct disciplinary and systems research critical to the continued superiority of U.S. aircraft. Systems integration requires that

technical disciplines, usually treated in isolation at the basic level, be interrelated through systems research.

- Ensure the timely transition of research results to the U.S. aerospace community. For efficient, timely transfer of technologies to industry, increased attention must be given to active participation of industry in NASA's research and technology development through contractual and joint programs; timely dissemination of results through workshops, conferences, and reports; and dissemination to industry of information on technology advances made outside the United States.

- Ensure the involvement of universities and industry in NASA's Aeronautics program. NASA grants and contracts are an incentive to academic expertise in the university community and encourage technology development by industry for incorporation into new vehicle designs.

- Provide development support to the aeronautics activities of other government agencies and U.S. industry. While furnishing that service, NASA gains data and experience of benefit to its primary mission of aeronautical research and technology development.

Decisions on funding, personnel, and facilities for the program must be consistent with the program's long-term technology development objectives, which would:

- Bring external and internal computational fluid dynamics to a state of practical application for aircraft and engine design

- Significantly reduce aircraft viscous drag over the full speed range and improve understanding of Reynolds number effects at transonic speeds

- Through the use of advanced materials, minimize the structural weight of civil and military aircraft engines and airframes

- Provide advanced control, guidance, and flight management systems to improve performance and operation of future aircraft

- Increase by 100 percent the productivity and reliability of rotorcraft for military and civil application

- Ensure the availability of technology for superior military aircraft and missile systems

- Enhance flight crew effectiveness in advanced cockpit and air traffic environments that include advanced automation, display, and control techniques

- Exploit modern computers in solving computationally intensive aeronautical problems

- Exploit the full potential of techniques for enhanced performance through highly integrated propulsion-airframe systems

- Advance the technology for small gas turbine engines to a level comparable with that for large turbine engines
- Establish the technical feasibility of high-speed turboprop propulsion
- Advance enabling technologies for subsonic transport engines to improve their fuel efficiency and durability
- Increase aviation safety by improving crash and fire worthiness, protection from weather hazards, and aircraft systems.

The program will continue efforts both in basic aeronautical disciplines and in systems research and technology development. The principal areas of technology currently being pursued include: fluid and thermal physics--high Reynolds number cryogenic testing, viscous drag reduction, vortex flows, and computation of the aerodynamics of complex aircraft configurations; materials and structures--light alloy metals, new composite materials, and the crash dynamics of composite structures; controls, guidance, and human factors--aircraft with highly augmented controls, fault-tolerant systems, advanced automation of crew stations, and improved simulation; computer science--concurrent processing architectures, algorithms, and techniques for computational physics research; propulsion--advanced turboprop, small turbine engine, and general aviation and commuter aircraft engine technology; rotorcraft--noise and vibration reduction and unsteady rotor aerodynamics; high-performance aircraft--high angle-of-attack flight, vectored-thrust and short-takeoff-and-vertical-landing aircraft, maneuverable supersonic cruise aircraft, propulsion-airframe integration, increased engine performance and durability through the turbine engine hot section technology program, and hypersonic propulsion, structures, and configuration aerodynamics; and subsonic aircraft--icing and lightning research, natural and controlled laminar flow, and, in coordination with the Federal Aviation Administration, air safety, operations problems, and interfacing with the Air Traffic Control System.

Technical progress during the past year has permitted acceleration of work on advanced turboprops and oblique wings. In an effort to initiate a full-scale flight test of the Advanced Turboprop propulsion concept by 1987, NASA has augmented the Advanced Turboprop work dedicated to the flight test. Work in the oblique wing program now is directed toward flight demonstration and validation tests of the use of oblique wings at transonic and supersonic speeds.

Planned initiatives include development of technology in the following areas to respond to technical opportunities and needs and to satisfy the long-term technology development objectives listed previously:

- High-speed (hypersonic) flight--to provide a proven technology base for future options in aeronautics and space in the critical areas of air-breathing propulsion, aerothermodynamics, materials, structures, and system analysis, including the development of a recoverable hypersonic research aircraft
- Supersonic cruise--to obtain long distance efficiency for future military and civil aircraft

- o Computational fluid dynamics--to facilitate development of focused applications of computational fluid dynamics for important 3-dimensional viscous-dominated flows and development of pathfinding simulations of the fundamental physics of unsteady flows; to initiate development of techniques for performing integrated multidisciplinary analyses; and to apply expert systems to automating development of computational fluid dynamics analyses

- o Rotorcraft systems noise and vibration--to develop design methodology for future helicopters that will be acceptable to the community, have low vibration, and without sacrificing vehicle performance, have low acoustic detectability (for military applications)

- o Advanced fighter aircraft--to accelerate and integrate key enabling technologies, such as those for high thrust-to-weight propulsion, thrust vectoring for control, and high-angle-of-attack flight dynamics, for revolutionary advances in fighter capabilities

- o Transport aircraft laminar flow--to provide flight verification of a hybrid wing concept employing active laminar flow control in leading edges for a new generation of fuel efficient civil and military transports

- o Small-engine components--to provide major improvements in the fuel consumption, weight, reliability, and durability of small turbine engines for a broad range of future military and civil applications

- o Superaugmented rotorcraft--to achieve an all-weather operational capability for a single-pilot helicopter and for operations at remote sites or in emergency medical services

- o Convertible engine propulsion--to provide integrated flight and propulsion control modes for convertible powered rotorcraft and to evaluate advanced convertible engine concepts

- o Composite structures--to achieve effective use of advanced composites in highly loaded airframe structures

- o Advanced transmission systems--to produce more reliable, more efficient, and lighter weight transmissions for advancd turboprop, geared turbofan, and rotorcraft

- o Supersonic STOL/STOVL aircraft--to provide technology for advanced, supersonic, STOL/STOVL fighters able to operate from a variety of surfaces

- o STOVL experimental aircraft--to conduct flight tests of advanced STOVL aircraft concepts.

E. Aeronautics Beyond the Year 2000

At the end of the 20th century, a substantial potential will still exist for major advances in each of the aeronautical disciplines--aerodynamics, structures and materials, propulsion, and controls--and, perhaps of even more

significance, in abilities to combine individual advances into integrated technology for totally new aircraft systems. In addition, continued progress in related areas such as electronics, computer science, artificial intelligence, fiber optics, laser technology, and quite probably some fields not yet identifiable, will increase further the potential for progress in aeronautics over the next century.

Technologies for conventional subsonic transports, general aviation, and helicopters, all of which are major integral components of today's aviation, will continue to be important for many years into the next century. NASA will continue to develop technology for necessary improvements in the safety, productivity, and operational effectiveness of subsonic transports and in the efficiency, safety, and automation of the tasks performed by general aviation pilots. Increases in the all-weather capability and productivity of conventional helicopters and reduction of their noise and vibration will greatly expand their use in civil transportation, as well as in the special-purpose, utility, and military missions they perform today.

But probably of even more significance will be new opportunities and challenges connected with supersonic cruise, high-speed rotorcraft, short-haul subsonic transportation, and hypersonic flight.

1. Supersonic Cruise

Advances in supersonic cruise technology will provide important options for civil transportation, as well as for military aircraft. The next century will be characterized by several trends that are almost certain to alter the outlook for long-range transportation. World population will continue to grow, and the largest component of that growth--over 75 percent--will be in the developing nations. The growth of population and industry in the Pacific Basin, South America, Asia, and Africa--and the resulting increase in trade and multinational business--will create a market for over-ocean transportation with stage lengths considerably greater than those over the North Atlantic. Those long stages and the large fraction of travel that will be business oriented, rather than tourist oriented, will increase the value of reducing trip time and increasing productivity, and will precipitate renewed interest in supersonic transportation.

The Concorde already has proven the technical feasibility of supersonic air transportation, but also has proven that a system based on technology of the 1960s cannot be economically viable. Research conducted since termination of the U.S. supersonic transport program has resulted in considerable optimism that a supersonic transport can be economically viable and environmentally acceptable. Design studies conducted by the major aircraft manufacturers indicate that an advanced technology supersonic transport could carry 300 to 400 passengers over intercontinental ranges at more than three times the speed and productivity of today's subsonic transports. Operating cost estimates suggest that little if any surcharges over tourist fares would be required, and some configuration approaches appear to promise sonic boom overpressures that would be sufficiently low that flight over land would be practical.

Supersonic-cruise technology also is important for development of combat aircraft. Recent studies and combat experience indicate that sustained supersonic cruise, coupled with high maneuver capability, would provide a

considerable increase in combat effectiveness and survivability. In addition, the higher engine installed thrust-to-weight ratios associated with supersonic cruise capabilities increase the feasibility of short takeoff and vertical landing capabilities for future fighters.

2. High-Speed Rotorcraft

Although an order of magnitude slower than supersonic aircraft, new rotary-wing vehicles will be much faster than present-day helicopters and, therefore, able to assume a much broader role in both civil and military operations. Tilt-rotor technology developed jointly by NASA and the U.S. Army makes it possible for an aircraft to retain the vertical flight and hover advantages of a helicopter while being capable of efficient, smooth, quiet, forward flight at speeds approaching those of current propeller-driven airplanes. That capability is a first, but important, step toward entirely new generations of high-speed rotary wing aircraft for a variety of military applications and for civil missions including rescue, emergency medical service, and police work.

The tilt-rotor aircraft's increased speed, range, economy, payload, and comfort will provide the basis for large-scale inter-city and inter-region civil transportation. Also, its capability for combined vertical and forward flight will be important in satisfying worldwide needs created by conditions as disparate as urban congestion in highly developed areas and primitive terrain in developing areas. Problems encountered in construction activities at remote sites may focus future attention on another feature of rotary-wing technology--the heavy lift capability of very large helicopters, particularly in the higher-efficiency, reduced-weight versions that current rotorcraft research will make possible.

3. Short-Haul Transports

Although supersonic transports will provide much of future long-range air travel, a large fraction of air transportation in the United States and, even more, in Europe and elsewhere will consist of trips with stage lengths of 160 to 800 kilometers. In the next century, as population grows and shifts away from the older metropolitan areas and as new urban areas and industrial centers develop, the need for efficient, comfortable, short-haul air transportation will increase rapidly. Small commuter aircraft mostly will be replaced by aircraft that have capacities of 50 to 100 passengers or more, that are designed to large-transport standards of air worthiness, operation, safety, and dependability, and that also are designed for maximum efficiency during climb, descent, and short-stage-length flight. The new aircraft also will be able to operate safely and quietly at relatively small airports and on short runways at hub terminals.

Advanced turboprop technology now under development will be an important contributor to that future generation of commuter aircraft by providing important improvements in fuel economy. The new short-haul transports also will benefit from research now under way for long-haul transports in areas such as drag reduction, lightweight structures, active controls, and safety. They also may employ propulsive lift for takeoffs from short runways.

4. Hypersonic Flight

The X-15 research airplane allowed some exploration of the hypersonic regime in the early 1960s and, in fact, helped set the stage for the Shuttle and other space vehicles that must pass through the hypersonic regime on the way to and from orbit. Development of capabilities for sustained hypersonic flight entails technical problems in propulsion and aerodynamic heating that will be more difficult to solve. However, research has indicated that they can be solved, making hypersonic flight operations in the next century practical and perhaps even routine. Long-range cruise missiles with supersonic-combustion ramjet (scramjet) propulsion systems burning high-density hydrocarbon fuels may be the first generation of operational hypersonic vehicles, followed by strategic reconnaissance aircraft able to cruise at Mach 5 to Mach 7 at very high altitudes. There also is renewed interest in a hypersonic maneuvering airplane capable of sustained operation both in the atmosphere and in low orbit. Equipped with a combination of scramjet and rocket propulsion to match the transatmospheric envelope, it probably would be able to take off, as well as land, horizontally. Technology development involving highly coordinated systems research in the propulsion, aerodynamics, materials, structures, and controls disciplines will be required and will have to be conducted on the basis of postulated future vehicle requirements until actual military spaceflight needs can be defined.

5. Research Opportunities

The Aeronautics Research and Technology Base effort, the primary source of the seeds for long-range future growth, well may lead to additional and perhaps even more important next-century developments that now cannot be identified. Two areas of extreme importance to developments in all the types of aeronautical vehicles are the growing dependence of aircraft and engine design on numerical simulation and the use of microelectronics in aircraft controls.

An ability to compute fluid dynamics is essential for enhancing understanding of aeronautical phenomena and for facilitating the aeronautical design process. By the year 2000, solutions to the full Navier-Stokes equations should be possible, providing exact solutions for the real flow of gases, allowing accurate modeling of turbulence and separated flow, and opening the way to a broad range of control mechanisms for improving aerodynamic flows.

Technology advances that should be incorporated into aircraft of the next century will require that systems integration capabilities be developed to a degree more advanced than those reflected in the Space Shuttle, the best current example of a highly integrated aerospace vehicle. Highly reliable flight controls, electric power systems, and electromechanical actuators will allow replacement of mechanical, hydraulic, and pneumatic systems with all-electric systems having higher reliability and lower weight. Fiber optics will make possible fly-by-light systems providing still greater flexibility, weight reduction, and protection from lightning effects. Technology will be available for active controls to alleviate structural loads and suppress flutter, thereby significantly improving ride qualities and reducing pilot workloads and structural fatigue.

Many of the tools and facilities that will be required to support research and technology and vehicle development into the 21st century either already exist or are under development. NASA's impressive capability in low-speed and high-speed wind tunnels recently has been augmented with the National Transonic Facility and will be enhanced further when the 40X80X120-foot wind tunnel at Ames Research Center becomes operational. However, additional capabilities will be needed for large-scale, real-gas, hypersonic engine testing, for icing research, and for large-scale, integrated airframe-propulsion systems research in which altitude, temperature, and speed effects can be studied concurrently.

In addition to those types of ground-based facilities, technology development will continue to require flight research as an essential element. Thus, new experimental vehicles probably will be required in the areas of hypersonics, supersonic hort-takeoff and vertical landing, advanced supersonic cruise aircraft, and very high speed rotorcraft.

The future of aeronautics in the next century is replete with technology opportunities for growth and advancement even more impressive and exciting than those witnessed in the present century, but successful realization will require continued effort and commitment. NASA's research is providing, and will continue to provide, a solid foundation from which NASA will proceed effectively in directions it selects on the basis of national needs and priorities.

F. Institution

Two of the eight NASA goals listed in Section A of this chapter, the first and the last, are fundamental to institutional management. As an important step toward meeting the first, creation of a work environment that will enable the Agency to achieve and maintain a work force of highest excellence, NASA has undertaken as a priority activity recruitment of recent graduates of distinction in science and engineering. The current scientist and engineering complement of 10,900 is expected to grow to approximately 11,500 by the end of FY 1989. Of particular significance is that the buildup is occurring within a stable ceiling of about 21,000 for NASA's total permanent work force.

The last of the eight goals calls for developing and applying advanced technology and management techniques and procedures to obtain optimum productivity. Two major activities are being conducted toward meeting that goal. The first is preservation, enhancement, and construction of aeronautical and space facilities, especially facilities essential to support the growing number of Space Shuttle flights and the payloads they carry. The second, computer systems management, has the objectives of ensuring that the best computer tools are available at the right time and at the lowest cost, fostering the use of computer systems to increase management productivity, and advancing computer and computer-related technology for the benefit of NASA and the Nation.

APPENDIX 7

Report of the White House Science Council

May 1983

OFFICE OF SCIENCE AND TECHNOLOGY POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20500

THE WHITE HOUSE

WASHINGTON

May 20, 1983

Dr. G. A. Keyworth, II
Science Advisor to the
President
Washington, D.C. 20500

Dear Jay:

The White House Science Council at its meeting today reviewed and approved the report of its Federal Laboratory Review Panel. I am pleased to transmit the report to you herewith.

As David Packard, the Panel's chairman points out, the Federal laboratories have several serious deficiencies, and a number of the laboratories do not meet the quality and productivity standards that can be expected of them.

Implementation of the Panel's recommendations would help overcome many of these deficiencies and better utilize the great potential of the laboratories. I urge you to help see that these recommendations are, in fact, acted upon expeditiously. The Council stands ready to help, as appropriate.

Sincerely,

Sol

Solomon J. Buchsbaum
Chairman
White House Science Council

Attachment
(1) Ltr. from David Packard, 5/12/83
(2) Federal Lab Report, May 1983

HEWLETT-PACKARD COMPANY
1501 PAGE MILL ROAD
PALO ALTO, CALIFORNIA 94304

DAVID PACKARD
CHAIRMAN OF THE BOARD

May 20, 1983

Dr. Solomon J. Buchsbaum
Chairman
White House Science Council
Executive Office of the President
Office of Science and Technology Policy
Washington, D. C. 20500

Dear Sol:

I am pleased to transmit to you, with this letter, the report of the White House Science Council's Federal Laboratory Review Panel.

In summary, the Panel found that the Federal laboratories have several serious deficiencies, and consequently, a number of the laboratories do not meet the quality and productivity standards that can be expected of them. We cannot overemphasize the need to correct these deficiencies.

The Panel's most important recommendations concern the missions and management of the laboratories. First, the parent agencies of the Federal laboratories must review and redefine the missions of these laboratories. At most multiprogram laboratories, the research activities could be reduced in breadth, and reconcentrated on those areas most relevant to the missions and of demonstrated excellence. The size of a laboratory must be determined by its mission requirements and by the quality of its work.

Second, the laboratories must be held more accountable for the quality and productivity of their research and development. There should be an oversight function that is responsible for the continuing excellence of the laboratories. This function could be performed by an external oversight committee. Micromanagement, or excessive detailed direction to the laboratories, focusing on procedures rather than content, should be stopped.

Dr. Solomon J. Buchsbaum May 20, 1983

The Panel has also made recommendations to relieve the constraints on Federal laboratories with regard to personnel administration; to provide funding in a way more conducive to rational planning; and to increase the collaboration of Federal laboratories with universities and industry. This last point is certainly not the least important. At a time when the nation's economic and defense leadership is increasingly challenged, greater synergism between all our R&D institutions is a must.

Sincerely,

David Packard

DP/lgk

FINDINGS AND RECOMMENDATIONS

The Federal Laboratory Review Panel was established by the White House Science Council. Dr. George A. Keyworth asked the Panel to review the Federal laboratories and to recommend actions to improve their use and performance. The Panel has completed an extensive survey of both government-operated and contractor-operated laboratories. The Panel is convinced that the Federal laboratories have great potential and are an essential part of the American institutions where R&D is performed and scientists and engineers receive training. At the same time, the Panel has observed a number of serious deficiencies in the Federal laboratories. These deficiencies limit both the quality and the cost-effectiveness of research done by the Federal laboratories. The negative effects of these deficiencies have increased to serious levels during the past decade.

The Panel has focused on several major aspects of the Federal laboratories, including *mission*—important for defining the relationship of these laboratories to other scientific institutions and also for assuring the best performance of each laboratory; *personnel*—the key laboratory resource upon which excellence depends; *funding*—an important factor in the laboratory's stability and long range organizational integrity; *management*—crucial in creating and maintaining an environment conducive to first class research; *interaction of the Federal laboratories with universities, industry, and users of research results*—necessary for greater relevance and usefulness of the laboratories' research results.

In this summary, we present the Panel's major recommendations. We believe they demand the attention of both the Administration and Congress. At a time when the nation's economic and military competitiveness is increasingly challenged, it is imperative that the nation gets the optimum return from its investment in the Federal laboratories. The Panel believes that all the recommendations, if implemented, will improve the quality of the work done by the Federal laboratories.

1. *Mission*

The Panel believes that clearly defined missions consistent with the appropriate roles for Federal laboratories*, are important to the vitality of any laboratory. Of the laboratories visited, those with well defined missions clearly were better performers than those with poorly defined missions. Those laboratories with both well defined missions *and* close interaction with the users of their research appeared to be the most effective of all.

* The appropriate roles for Federal laboratories are discussed in the Introduction section of the report.

Recommendations

1-1. As a top management priority, Federal agencies should reexamine the missions of their laboratories. Together with the laboratory directors, the agencies should redefine the missions as necessary to ensure that they are consistent with the appropriate roles for Federal laboratories. The missions must be made sufficiently clear and specific to guide the agency and the laboratories in setting goals against which the laboratories' performance can be evaluated.

1-2. The size of each Federal laboratory should be determined by its missions and the quality of its work. That size should be allowed to increase or decrease (to zero if necessary) depending on mission requirements, but it should not fluctuate randomly. Preservation of the laboratory is *not* a mission.

2. *Personnel*

The Panel believes that almost all of the Federal laboratories, both government-operated and contractor-operated, suffer serious disadvantages in their inabilities to attract, retain, and motivate scientific and technical personnel required to fulfill their missions. The principal disadvantage is the inability of the Federal laboratories, particularly those under the Civil Service system, to provide scientists and engineers with competitive compensation at entry and top senior levels.

Recommendations

2-1. Administrative and legislative actions should be initiated now to create, at government-operated laboratories, a scientific/technical personnel system independent of current Civil Service personnel systems.

2-2. Contracts governing government-owned, contractor-operated laboratories should be rewritten to permit the contractor to establish and carry out an independent salary administration.

3. *Funding*

The Panel is concerned that the direction and performance of the Federal laboratories is less than optimal because of serious problems with the continuity of research funding. Supporting high quality research requires stability and a long-range view.

The Panel also believes that the Federal laboratory directors are not allowed enough flexibility to exploit innovative scientific opportunities. However, added flexibility will be an improvement only if accompanied by increased accountability for performance and results.

Recommendations

3-1. The Congress and the Office of Management and Budget should authorize funding for R&D programs on a predictable multiyear basis so that staffing levels and research activities at the Federal laboratories can be properly planned.

3-2. At least 5 percent and up to 10 percent of the annual funding

of the Federal laboratories should be devoted to programs of independent research and development at the laboratory directors' discretion. Federal agencies should establish a mechanism to evaluate the results of such work, with the size and continuation of discretionary funds related to laboratory performance. In order to encourage cooperative research programs, the laboratory directors should have the authority, and be encouraged, to spend part of the discretionary funds at appropriate universities and industries.

4. Management

The Panel concludes that some agencies give excessively detailed management direction to the laboratories (i.e. micromanagement). At the same time, they do not hold the laboratories sufficiently accountable for output in terms of quality and productivity.

Recommendations

4-1. For each Federal laboratory, there should be an external oversight function responsible for assuring the continuing excellence of the laboratory. This function could be performed by a committee which should include strong industry and university representation. This committee would spend enough time at the laboratory to become familiar with the laboratory's strengths and weaknesses. It would focus on productivity *and* on the excellence, relevance, and appropriateness of research. The oversight committee would make recommendations to the agency and inform the laboratory director of these recommendations. Those recommendations would be taken into account by the agency and laboratory in their budget decisions. In addition, the committee would also give special attention to reducing micromanagement by the sponsoring agency.

4-2. Federal agencies should rely to a greater extent on the competitive peer review process for funding basic research at the laboratories.

4-3. The laboratory director must be held accountable for the quality, relevance, and productivity of the laboratory. Appointment of the director should be for a finite term, with the option of extending or abbreviating the term depending on the performance of the director and the laboratory.

5. Interaction with Universities, Industry, and Users of Research Results

The Panel feels that the degree of interaction of Federal laboratories with universities and industry varies among laboratories, but has not been strong traditionally. The national interest demands that this collaboration be stronger to ensure continued advances in scientific knowledge and its translation into useful technology.

Recommendations

5-1. Federal laboratories should encourage much more access to their facilities by universities and industry.

5-2. R&D interactions between Federal laboratories and industry should be greatly increased by more exchange of knowledge and personnel, collaborative projects, and industry funding of laboratory work, provided an oversight mechanism is established to prevent unfair competitive practices.

5-3. Contracting by agencies and laboratories for universities and industry to conduct R&D should be encouraged by simplifying the necessary Federal procurement procedures. The procurement process should give laboratory directors greater flexibility in contracting.

6. Conclusion

In addition to the major recommendations contained in this summary, there are several others in the body of the report. We believe that the Panel's recommendations, when implemented, will make constructive changes to revitalize the Federal laboratories so that their wealth of talent and facilities will contribute more effectively to our citizens' health, our nation's defense, and our economic growth.

Contents

	Page
Introduction	1
1. Mission	4
2. Resources: Personnel	6
3. Resources: Funding	8
4. Management	9
5. Interaction with Universities, Industry, and Users of Research Results	11
Acknowledgements	13
Appendix A: White House Science Council Laboratory Review Panel	A-1
Appendix B: Laboratories Visited by White House Science Council Laboratory Review Panel	B-1
Appendix C: Past Studies Reviewed by Federal Laboratory Review Panel	C-1
Appendix D: Sources of Industry Input to Federal Laboratory Review Panel	D-1
Appendix E: NOSC/NWC Personnel Demonstration Project	E-1

INTRODUCTION

Background

The White House Science Council's Federal Laboratory Review Panel[1] was appointed by Dr. Solomon J. Buchsbaum, Chairman of the Council, in March 1982. Dr. George A. Keyworth, Science Advisor to the President, asked the Panel to review the Federal laboratories and to recommend actions to improve their use and performance. The Panel was specifically charged to look at laboratory missions, identify any systemic impediments to performance, and determine whether this nation is getting the optimum return on its substantial investment in talent and facilities at the Federal laboratories.

There are more than 700 Federal laboratories, set up at various times for specific purposes. Over time, their activities have tended to expand and diversify, partly because they succeeded in their original tasks and partly because mission requirements changed. In some cases, this expansion has resulted in a dilution and weakening of purpose, mission, and capability.

Panel Activities

Of the Federal agencies with research and development (R&D) laboratories, the Panel concentrated on six with the major share of laboratory funding: The Departments of Defense, Agriculture, Commerce, Energy, and Health and Human Services, and the National Aeronautics and Space Administration. Panel members visited several large multiprogram R&D laboratories[2] and met with top agency representatives responsible for laboratory management. The Panel also examined past studies of Federal laboratories[3], and was kept informed of ongoing reviews by the President's Private Sector Survey and the Energy Research Advisory Board. The Panel invited input from industry and universities and took those into account in its deliberations[4].

Overall Findings

The Panel did not review the Federal laboratories in sufficient detail to evaluate fully the quality of the work being done or to measure the Federal laboratories' contributions in relation to university and industrial research. The Panel did find highly competent people, important research programs, and unique large facilities that would be beyond the means of both universities and industry. The Panel also identified a number of serious deficiencies at the Federal laboratories that limit both the quality and cost effectiveness of the work done there. These deficiencies are not new, but their negative effects have increased to serious levels over the past decade. The nation's return on its investment in support of the laboratories is being undercut seriously by vagueness and inconsistencies in some of the laboratories' missions,

[1] See Appendix A for a list of Panel members.
[2] See Appendix B for list of laboratories visited
[3] See Appendix C for list of major past studies
[4] See Appendix D for individuals, corporations and organizations

and by the increasingly pervasive effects of impediments described later in this report.

R&D Roles

The Panel believes that Federal laboratories play important roles in the nation's scientific and engineering enterprise—roles that complement those played by industry and universities. Specifically, the Panel believes that these roles are appropriate for the Federal laboratories:

- Perform basic and applied research in areas where the Federal government has a legitimate responsibility, including nuclear energy, agriculture, health sciences, and development of military technology and equipment.
- Conduct other research projects of a long range nature that require unique, capital-intensive facilities and multidisciplinary approaches.
- Build and manage large multiuser technical facilities, and encourage universities and industry to use them.
- Contribute, through cooperative programs with universities, to the education of scientists and engineers in applied research where university capabilities may be limited.
- Perform research and provide services on important national standards, metrology, environmental protection, health and safety.
- Provide special services, such as producing radioactive material, maintaining banks or libraries of materials (such as agricultural plant material), and provide calibration services such as those relating to time, and other physical measurements.
- Develop commercial products only when that work has industry cooperation *and* is directly related to the laboratory's unique capabilities.

These roles are intermediate between those of universities and industry. Both Federal laboratories and universities are very important to support a high rate of technological advance in the U.S. Universities often excel in basic research, and they provide the additional important benefit of producing future scientific talent. On the other hand, Federal laboratories and commercial firms have many common capabilities and interests. Commercial firms are, by far, the most effective in applying research results to broader, practical uses, and to deliver products and services to the market. They also have the best capability to conduct activities to improve industrial competitiveness and productivity. The national investment in R&D must be justified by the contributions of the R&D institutions to the nation's goals of health, strong economic growth and national defense. These contributions can be optimum only if these institutions fulfill their proper roles and complement one another, so that their research contributes to U.S. leadership in technologies and products. The balance in Federal funding between Federal laboratories, universities, and commercial firms may not be optimum and needs further attention.

Nature of Recommendations

The recommendations in this report are made in the framework of the roles described above. They aim to bring the Federal laboratories to the necessary level of excellence and productivity to justify a continuing high level of investment in them. The Panel believes strongly that action on these recommendations, some of which have been made before, is well overdue. The Administration and the Congress can and should make major corrections in 1983 to improve the quality and productivity of the Federal laboratories.

The recommendations address the following factors, which are vital to the laboratories' ability to perform and to contribute to the nation's well-being and national security:

- Clear *missions* that allow firm goals to be set against which the performance of the laboratories can be measured.
- Appropriate *resources*, most importantly adequate scientific talent, for carrying out the missions.
- A *management* of the laboratories that fosters an environment conducive to first-class research.
- Strong *interaction with universities, industry, and users of research results*, to maximize the complementary use of talent and resources; to assure application of results to broader, practical uses; and to minimize undue overlap and unfair competition.

1. MISSION

The Panel believes that clearly defined missions are important to the vitality of any laboratory. Of the laboratories visited, those that had well defined missions clearly were better performers than those that did not. Those laboratories which had both well defined missions *and* close interaction with the users of their research seemed the most effective.

The Panel observed that some of the laboratories did have a clearly defined mission for a part—often a major part—of their work, but the balance of the work was often fragmented and unrelated to their main activity. This phenomenon frequently occurs when a national need that justified the original mission of a laboratory becomes of lower priority. The laboratory then tends to diversify into other work to occupy its staff and preserve institutional stability. The DOE laboratories offer an example of this tendency. During the mid-1970s, work related to their original missions under the Atomic Energy Commission decreased. Research on alternate energy resources was used to fill the gap and increase the activity level at several of the large DOE laboratories. The new missions were not very clearly defined or carefully considered at any level of management.

Given the great concern at that time about future energy sources, a lot of money was made available to the laboratories. But, very little came of this effort, and in the 1980s most of the research on alternate energy resources has been cut back, transferred to industry, or transformed into longer-term exploratory development. These changes have left several of the DOE laboratories without well defined missions. The absence of missions, in turn, contributes to less than optimum use and performance.

The Panel believes that the clearer a laboratory's missions are, the better its performance will be. It would be better to reduce the size of a laboratory to meet the real needs of its legitimate missions than to maintain its size by filling in with unrelated research projects.

A laboratory whose original missions no longer serve high-priority national needs may be able to acquire new missions. To be carried out competently, these missions must be consistent with the laboratory's existing strengths and expertise. If necessary, a laboratory without a mission should be shut down.

The Panel also concludes that some of the work done by the Federal laboratories could have been done as well, or possibly better, by private industry or by universities (e.g., engine designs, batteries and fuel cells, electric power transmission and distribution, design of specific airframe/engine installation concepts, and renewable energy sources). This would have been less likely to happen if the missions of the Federal laboratories had been defined to encourage cooperation rather than competition with industry and universities. Most research projects at Federal laboratories could benefit from related research in universities

and in industry and could be guided by prospective users, either in industry or in government agencies.

Finally, the Panel observed a certain amount of overlap and competition between some laboratories, but this should not be a problem if the main missions are clearly defined. Some competition is good. For example, the competition between Lawrence Livermore and Los Alamos in nuclear weapons development seemed to be an important factor in the high quality of weapons work in both laboratories.

The breadth of research activities at most Federal laboratories could be reduced and the depth increased in those areas of demonstrated excellence and mission relevance. The laboratories could also take better advantage of modern communications technology for information exchange among a large number of people over wide geographic areas.

Recommendations

1-1. As a top management priority, Federal agencies should reexamine the missions of their laboratories. Together with the laboratory directors, the agencies should redefine the missions as necessary to ensure that they are consistent with the appropriate roles for Federal laboratories. The missions must be made sufficiently clear and specific to guide the agency and the laboratories in setting goals against which the laboratories' performance can be evaluated.

1-2. The size of each Federal laboratory should be determined by its missions and the quality of its work. That size should be allowed to increase or decrease (to zero, if necessary) depending on mission requirements, but it should not fluctuate randomly. Preservation of the laboratory is *not* a mission.

2. RESOURCES: PERSONNEL

The key to a laboratory's success is a high quality and properly motivated scientific staff. The inability of many Federal laboratories—especially those under Civil Service constraints—to attract, retain, and motivate qualified scientists and engineers is alarming. The personnel problem is most serious at government-owned, government-operated laboratories (called GOGO's) but it also affects government-owned, contractor-operated laboratories (GOCO's). At present, this situation limits the productivity of the laboratories. If not corrected, it will seriously threaten their vitality.

While middle level salaries may be competitive, the GOGO's have difficulty attracting young scientists and engineers at the entry level (GS-5 and 7) on one hand, and very experienced and qualified top-level personnel on the other. There are many reasons for this difficulty, but the main one is noncompetitive pay and benefits compared with industry and universities[1]. Furthermore, cumbersome procedures for hiring new staff make it hard to bring in new talent even when other obstacles have been overcome.

The rigidity of the Civil Service promotion and salary system limits rewards for outstanding scientists and engineers. Many of them leave the GOGO laboratories when they reach the levels where they cannot advance unless they are willing to assume management and administrative responsibilities (usually GS-12 and 13 levels). Promotion is linked to management responsibilities, and current rules do not allow for adequate recognition of scientific performance alone. Recent personnel ceilings imposed strictly on a numerical basis without distinguishing among types of staff have adversely affected the laboratories' R&D activities.

The GOCO's are not legally under the Civil Service system, but some agencies have chosen to impose ceilings on allowable reimbursements for scientific personnel.

This personnel situation leaves the Federal laboratories vulnerable to weak scientific leadership if senior qualified personnel cannot be replaced, and to declining quality of research because of inadequate infusion of young talent.

It is important that Federal laws and regulations be modified to exempt scientific and engineering personnel at Federal laboratories from the unduly rigid hiring, salary, and promotion rules of the Civil Service system. In place of these rules there should be: 1) a more flexible system that facilitates hiring, and enhances career progress for

[1] The pay discrepancy varies among laboratories. The National Institutes of Health has the largest difference between the Federal pay ceiling and the private-sector earning power of specialized academic physicians.

technically qualified personnel, and 2) an effective performance-based reward system.

The recent experiment by the Department of Defense at the Naval Weapons Center (China Lake, California) and the Naval Ocean Systems Center (San Diego, California) is considered highly successful by the participants[9]. The experiment applies a revised personnel management system which simplifies classification and bases pay, appraisal, and retention on performance. It also reduces the paperwork required to hire and promote. The experiment shows that it is possible to introduce flexibility in personnel management at the government-operated Federal laboratories.

GOCO personnel problems can be corrected by a very simple and logical step. Every contract to manage a government laboratory—whether the contractor is an industrial firm, a university, or a nonprofit organization—should give the contractor complete authority to set and carry out personnel policies that will enable the laboratory to attract retain, and motivate its professional staff. The laboratory management must have authority to set and carry out personnel policies that are comparable with those of competitors. This can be done best by the laboratory management, not by the agency.

Recommendations

2-1. Administrative and legislative actions should be initiated now to create, at government-operated laboratories, a scientific/technical personnel system that is independent of current Civil Service personnel systems. The experimental system for managing scientific and technical personnel at the Naval Weapons Center and Naval Ocean Systems Center is an example of how this can be approached.

2-2. Contracts governing government-owned, contractor-operated laboratories should be rewritten to permit the contractor to establish and carry out an independent salary administration.

2-3. Personnel ceilings at government-operated laboratories should not be used in addition to budgetary control. Federal agencies should provide budget constraints and give the laboratory directors freedom to decide how to meet them. Laboratory directors should also be allowed to make the final decisions on contracting for support services at their laboratories.

[9] See Appendix E for description of experiment.

3. RESOURCES: FUNDING

The current processes by which laboratories are funded impede rational planning and effective conduct of R&D activities. The budget process consumes too much time at too many levels, both in the agency and the laboratories. Delayed appropriation actions by Congress, often compounded by agency indecision, have dragged uncertainties in laboratory funding well into the fiscal year in which funds are to be spent. It is also clear that most laboratory directors need more flexibility to allocate funds at their laboratories. However, added flexibility will be an improvement only if accompanied by increased accountability for performance and results.

If U.S. taxpayers are to get the most return from their support of R&D, government laboratories must have sufficient discretionary funding for independent research and development. Almost every laboratory has found that the most important innovation often comes from the scientists' independent ideas of actions. Thus, the productivity of the U.S. R&D establishment depends on a vigorous independent R&D program. Yet, funding for independent R&D has been decreasing over the years.

Recommendations

3-1. The Congress and Office of Management and Budget should authorize funding for R&D programs on a predictable multiyear basis so that staffing levels and research activities at Federal laboratories can be properly planned.

3-2. At least 5 percent, and up to 10 percent, of the annual funding of the Federal laboratories should be devoted to programs of independent research and development at the laboratory directors' discretion. Federal agencies should establish a mechanism to evaluate the results of such work, with the size and continuation of discretionary funds related to laboratory performance. In order to encourage cooperative research programs, the laboratory directors should have the authority, and be encouraged, to spend part of the discretionary funds at appropriate universities and industries.

3-3. Federal laboratories should be allowed to carry forward remaining funds into the next fiscal year. This would eliminate the wasteful practice of hurried spending at the end of each fiscal year.

4. MANAGEMENT

It is clear to the Panel that excessively detailed direction of laboratory R&D activities from agency headquarters, known as micromanagement, has seriously impaired R&D performance in some laboratories. Numerous detailed external directions are given as to how work should be done, while at the same time, the overall missions and goals of the laboratories are inadequately defined. This trend must be reversed.

The micromanagement problem is most serious at the Department of Energy (DOE) laboratories and has its roots in the lack of stability in the DOE itself. The Department has changed leadership many times, and its mission has changed and diversified too often, to the point where it is no longer clear. The Department also must respond to a much larger number of Congressional committees and subcommittees than other Federal agencies do.

Perhaps the most serious deficiency of the Federal laboratories is their lack of accountability. They are not subject to the competitive driving force of the peer review system as the universities are. Nor has their survival depended on satisfying the cost effectiveness and relevance constraints of industrial R&D laboratories. In the absence of economic and competitive forces, the Federal laboratories must be held accountable by their agencies. Unfortunately, in most cases, the agencies' oversight means an excessive amount of reporting and paperwork, but inadequate scrutiny of the quality and relevance of the laboratories' activities.

The current review mechanism often focuses on evaluation of proposed work rather than actual performance. Review processes also emphasize the more easily measurable criteria (e.g. time and cost) rather than the more difficult but important criteria of excellence, relevance to national needs, and appropriateness[1]. Review committees usually have only advisory authority and report to the laboratory directors.

As a result of this kind of oversight, there are many opportunities for low-quality research in pedestrian subjects or in areas inappropriate for government involvement. R&D in Federal laboratories, even within the same agency, is often poorly coordinated, leading to unproductive overlap among laboratories and missed opportunities for synergism.

A proper balance of basic research activities between the laboratories and the universities is important to maintain both the nation's scientific base and educational capability. A good way to assure a proper balance

---

[1] Excellence: Is this research of high quality? Is this researcher competent?

Relevance: Does this research address an important scientific question to solve a national need? Is it related to the agency's mission?

Appropriateness: Is this laboratory the best place to perform this research? Should the Federal government be funding this research?

is to insist upon excellence as a criterion for support. The competitive peer review process, though imperfect, is a good mechanism for evaluating basic research. Yet, among the agencies with major laboratories, only the National Institutes of Health rely on this process systematically and, even then, only for extramural programs.

Different agencies have different forms of laboratory management. Even within the Department of Energy, operating procedures differ: some laboratories are operated by universities, others by private companies, still others by government employees. Each form of management presents advantages and disadvantages, but the quality of management is crucial to a laboratory's performance. Federal agencies must insist on highly competent laboratory directors. The agencies must then make sure that the laboratory directors understand their missions and the place of their laboratories in the overall work of the agency. Each agency should involve the laboratory directors in developing an overall R&D plan. This would encourage teamwork and increase synergism between the laboratories.

Recommendations

4-1. For each Federal laboratory, there should be an oversight function responsible for assuring the continuing excellence of the laboratory. This function could be performed by an external committee which should include strong industry and university representation. This committee would spend enough time at the laboratory to become familiar with the laboratory's strengths and weaknesses. It would focus on productivity *and* on the excellence, relevance, and appropriateness of research. The oversight committee would make recommendations to the agency and inform the laboratory director of these recommendations. Those recommendations would be taken into account by the agency and laboratory in their budget decisions. In addition, the committee would give special attention to reducing micromanagement by the sponsoring agency.

4-2. Federal agencies should rely to a greater extent on the competitive peer review process for funding basic research at their laboratories.

4-3. The laboratory director must be held accountable for the quality, relevance, and productivity of the laboratory. Appointment of the director should be for a finite term, with the option of extending or abbreviating the term depending on the performance of the director and the laboratory.

4-4. The above recommendations apply to all Federal agencies. The management of the Department of Energy presents an additional special problem, and the Panel recommends that the Administration and Congress work together to stabilize and strengthen DOE management and to define and affirm its mission. Congress should also refocus its oversight of DOE R&D into a significantly smaller number of committees.

5. INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

The United States can no longer afford the luxury of isolating its government laboratories from university and industry laboratories. Although endowed with the best research institutions in the world, this country is increasingly challenged in its military and economic competitiveness. The national interest demands that the Federal laboratories collaborate with universities and industry to ensure continued advances in scientific knowledge and its translation into useful technology. The Federal laboratories must be more responsive to national needs.

The ultimate purpose of Federal support for R&D is to develop the science and technology base needed for a strong national defense, for the health and well-being of U.S. citizens, and for a healthy U.S. economy. Federal laboratories should recognize that they are an important part of the partnership with universities and industry in meeting this goal. A strong cooperative relationship must exist between Federal laboratories, universities, industry and other users of the laboratories' research results.

Federal laboratories have felt traditionally that they are part of the government, committed to its highest service and totally dependent on it for support. They perceived industry as an awkward partner with a different value system. Although the degree of interaction with universities and industry varied among the laboratories visited, the Panel feels that this interaction could be increased at all Federal laboratories.

One means of interaction is through R&D contracts. The current Federal procurement system discourages agencies and GOGO laboratories from contracting with universities and industry. Procedural requirements for doing so are far more cumbersome than for assigning work to the Federal laboratories. As a result, many parent agencies have assigned to the laboratories work that would be more appropriately performed elsewhere, and the GOGO laboratories have been reluctant to contract with universities and industry. The Panel believes that this situation has caused the balance of R&D funding in many agencies to shift in favor of the Federal laboratories at the expense of the universities and industry for over a decade. This problem is most severe with the DOE and DOD, and least with the NIH.

A final note on interaction between Federal laboratories and users of research results concerns the DOD. Since the major task of DOD laboratories is to enhance the capability of our military forces, greater communication between the DOD's operating forces and its laboratories would benefit both parties. This communication is currently hampered by the many layers of management between the laboratories and the operating forces.

Recommendations

5-1. Federal laboratories should encourage much more access to their facilities by universities and industry.

5-2. R&D interactions between Federal laboratories and industry should be greatly increased by more exchange of knowledge and personnel, collaborative projects, and industry funding of laboratory work, provided an oversight mechanism is established to prevent unfair competitive practices.

5-3. Contracting by agencies and laboratories for universities and industry to conduct R&D should be encouraged by simplifying the necessary Federal procurement procedures. The procurement process should give laboratory directors greater flexibility in contracting.

5-4. Support to the military operating forces should be an important criterion among others for measuring performance of the DOD laboratories.

ACKNOWLEDGE-MENTS

The Panel wishes to thank the directors and staff of the laboratories that we visited for their cooperation and assistance in the conduct of this review. The Panel also expresses appreciation to all the representatives from industry, universities, and government who formally and informally provided valuable input to the Panel.

APPENDIX A

WHITE HOUSE SCIENCE COUNCIL FEDERAL LABORATORY REVIEW PANEL

Panel Members

Chairman:	PACKARD, Mr. David Chairman of the Board Hewlett-Packard Company
Members:	BARDEEN, Dr. John Department of Physics University of Illinois
	BROMLEY, Dr. D. Allan Department of Physics Yale University
	FREDRICKSON, Dr. Donald S. Howard Hughes Medical Institute
	KERMAN, Dr. Arthur K. Department of Physics Massachusetts Institute of Technology
	TELLER, Dr. Edward Hoover Institution on War, Revolution and Peace, Stanford University
	WHEELON, Dr. Albert D. Space Communications Group Hughes Aircraft Company
Executive Secretary:	LING, Dr. James G. Office of Science and Technology Policy
Policy Analyst:	LETHI, Mrs. Minh-Triet Office of Science and Technology Policy

APPENDIX B

LABORATORIES VISITED BY WHITE HOUSE SCIENCE COUNCIL FEDERAL LABORATORY REVIEW PANEL

Laboratory	Date of Visit
Department of Agriculture	
Beltsville Agricultural Research Center	October 9, 1982
Department of Commerce	
National Bureau of Standards	November 28, 1982
Department of Defense	
Air Force Weapons Laboratory	June 21, 1982
Harry Diamond Army Laboratories	November 27, 1982
Naval Research Laboratory	November 27, 1982
Naval Weapons Center	December 14, 1982
Department of Energy	
Argonne National Laboratory	July 15, 1982
Brookhaven National Laboratory	August 30, 1982
Lawrence Berkeley National Laboratory	July 26, 1982
Lawrence Livermore National Laboratory	July 27, 1982
Los Alamos National Laboratory	June 21, 1983
Oak Ridge National Laboratory	August 31, 1982
Pacific Northwest Laboratory	July 28, 1982
Sandia National Laboratory	June 21, 1982
Department of Health and Human Services	
National Institutes of Health	November 28, 1982
National Aeronautics and Space Administration	
Jet Propulsion Laboratory	November 2, 1982

APPENDIX C

PAST STUDIES REVIEWED BY FEDERAL LABORATORY REVIEW PANEL

Department of Agriculture	Science for Agriculture. The Rockefeller Foundation and Office of Science and Technology Policy, 1982.
	An Assessment of the United States Food and Agricultural System. Office of Technology Assessment, 1981.
	Agriculture Rural Development and Related Agencies Appropriations for 1981. Part 4, pages 787 through 906, 1981.
	Report of the Committee on Research Advisory to the U.S. Department of Agriculture. National Research Council, 1972.
Department of Commerce	The National Bureau of Standards: A Review of Its Organization and Operations, 1971-1980. U.S. House of Representatives. Committee on Science and Technology. Subcommittee on Science, Research and Technology, 1981.
	Information on Mission and Functions of the National Bureau of Standards. General Accounting Office, 1981.
	National Bureau of Standards-Answers to Congressional Concerns. General Accounting Office, 1980.
	Selected Papers on the National Bureau of Standards. U.S. Senate. Committee on Commerce, Science and Transportation, 1978.
Department of Defense	USDRE Independent Review of DOD Laboratories. Robert J. Hermann, March 22, 1982.
	Research and Development for Military Strength: Concern and Recommendations. Center for Strategic and International Studies, Georgetown University, April 1982.
	Review of IR/IED Program at the NAVMAT R&D Centers. Memorandum for Mr. J. E. Colvard from Tibor G. Horwath, Headquarters Naval Material Command, April, 1981.
	Report of the DOD Laboratory Management Task Force, 1980.
	DOD Medical and Human Resources Laboratory Utilization Study, September, 1976.
	DOD Laboratory Utilization Study, 1975.
Department of Energy	Final Report of the Multiprogram Laboratory Panel; Volumes I, II and III. Energy Research Advisory Board, September, 1982.
	National Laboratories' Relationships with Industry and the University

Community. U S. House of Representatives, Committee on Science and Technology, 1981.

Changing the DOE's Headquarters/Field Organization Structure Could Provide a Better Framework for Accomplishing Departmental Objectives. General Accounting Office, 1981.

The Department of Energy Needs Better Procedures for Selecting a Contractor to Operate Argonne National Laboratory. General Accounting Office, 1981.

National Laboratories—Oversight, Legislation and Authorization Issues. Office of Technology Assessment, 1980.

Interagency Laboratory Use; Current Practices and Recurring Problems. General Accounting Office, 1979.

Review of Roles and Functions of the Laboratories and Operations Office (DESM 79-3). Department of Energy, 1979.

The Role of the National Energy Laboratories in ERDA and DOE Operations. William C. Boesman, Report to House Committee on Science and Technology, 1978.

The Multiprogram Laboratories—A National Resource for Nonnuclear Energy R&D. General Accounting Office, 1978.

Role of the National Laboratories in Energy Research and Development. House of Representatives, Committee on Science and Technology, 1978.

Field and Laboratory Utilization Study. Energy Research and Development Administration, 1975.

National Aeronautics and Space Administration (NASA)

Report on OSTP Study Group on Aeronautical Research and Technology Policy. Office of Science and Technology Policy, 1982.

Institutional Assessment. NASA, 1978.

Center Roles and Missions. NASA, 1976.

An Institutional Base Study. "McCurdy Study", 1971.

National Institutes of Health

Review and Evaluation of Intramural Research, A report to the NIH Scientific Directors. John C. Eberhart, November 3, 1982.

NIH Intramural Research Program Assessment. Offices of the Assistant Secretary for Health and the Assistant Secretary for Planning and Evaluation, Department of Health and Human Services, 1982.

The Intramural Programs of the NIH. Golberger Report, 1981.

Intramural NIH—Its Status and Prospects. Stetten Report, 1976.

Report of the President's Biomedical Research Panel, 1976.

Investigation of the NIH. House of Representatives, Committee on Interstate and Foreign Commerce, 1976.

All Federal Agencies

Multiyear Authorizations for Research and Development. General Accounting Office, June 3, 1981.

Federal R&D Laboratories Directors' Perspectives on Management. General Accounting Office, 1979.

Report to the President on Government Contracting for Research and Development. Bureau of the Budget for Committee on Government Operations, U.S. Senate, May 17, 1962.

APPENDIX D

SOURCES OF INDUSTRY INPUT TO FEDERAL LABORATORY REVIEW PANEL

Aerospace Corporation
Eberhardt Rechtin, President

Bell Laboratories
C.K.N. Patel, Executive Director
Research, Physics Division

Boeing Company
K. F. Holtby, Senior Vice President

Burlington Northern Railroad
Steven Ditmeyer, Director
Research and Development

Exxon
Peter Eisenberger, Director
Physical Sciences Laboratory

Duane Levine, Director
Science Laboratories

Ford Motor Company
Dale Compton, Vice President for Research

General Atomic
Harold Agnew, President

General Dynamics Corporation
L. F. Buchanan, Vice President
Engineering and Program Development

General Electric
Roland W. Schmitt, Senior Vice President
Corporate Research and Development

Robert C. Hawkins, General Manager
Advanced Technology Operations

Arthur Flathers
Aerospace Group

Craig S. Tedmon, Jr., Staff Executive
Power Systems Technology Operations

General Motors Research Laboratories
Robert A. Frosch, Vice President
General Motors Corporation

Grumman Corporation
Joseph G. Gavin, Jr., President

57-279 O - 87 - 56

IBM
Bill Howard, Office of Vice President and Chief Scientist

Lockheed Corporation
Roy A. Anderson, Chairman of the Board

McDonnell Douglas
Sanford N. McDonnell, Chairman of the Board and Chief Executive Officer

Northrop Corporation
Donald A. Hickes, Senior Vice President Marketing and Technology

Thomas V. Jones, Chairman of the Board and Chief Executive Officer

Rockwell International Corporation
Robert Anderson, Chairman of the Board and Chief Executive Officer

TRW, Inc.
John S. Foster, Jr., Vice President Science and Technology

Institute of Electrical and Electronics Engineers, Inc.

APPENDIX E

NOSC/NWC PERSONNEL DEMONSTRATION PROJECT

Area of Interest:

Demonstration Project
(An Experiment in Federal Personnel Management)

Background Statement

Under Title VI of the Civil Service Reform Act (CSRA) of 1978, there were provisions for federal agencies to obtain approval from the Office of Personnel Management to conduct a demonstration project to determine if the removal of personnel management constraints and changes to personnel regulations could increase effectiveness and efficiency in the work force. By law, such experiments were limited to a total of 10 active projects, could last for a maximum of five years, and were limited to a maximum of 5,000 employees.

To date only one project has been approved, and that is the Navy's joint Naval Ocean Systems Center/Naval Weapons Center Demonstration Project, initiated in July 1980. The Project allows waiver of certain personnel-related laws and regulations; however, it does not waive leave, insurance, annuity, Hatch Act, or EEO rules or regulations. Basically, it is a revised personnel management system providing simplified position classification, performance linked pay and appraisal, and performance based retention.

The following Executive Summary provides basic information on this Center's personnel Demonstration Project. Its purpose, description, and operating policies are covered. If you would like more detailed background on the Project, a suggested contact is:

Contact:

Bob Glen
Demonstration Project Manager (Code 0902)
Extension 3196

Executive Summary

Personnel management under the Civil Service system has experienced a number of problems; key examples are:

(1) Classification—complex and outdated position standards which delay recruitment and promotions, limit organizational flexibility to administer personnel resources, and place personnel staffs in an adversarial role with line management mission, product, and service obligations.

(2) Performance appraisal—unsatisfactory pay incentives to reward good and penalize poor performance, and the inability, through performance planning and mutual employee-supervisor goal setting, to objectively establish and measure employee effectiveness in relation to organizational goals.

(3) Merit pay—lack of sufficient incentives and flexibility in dealing with all levels of the work force and in offering recent college graduates and other potential employees pay which will keep pace with professional growth, performance and responsibilities demonstrated.

(4) Reduction-in-force—inability to recognize performance as a major criterion in RIF situations and to avoid adverse effects upon good performers who happen to have low retention standing or who may be recently-hired female or minority employees.

The NOSC/NWC Demonstration Project was established to address the above problem areas within the existing personnel system and to show that the effectiveness of federal organizations can be enhanced by allowing greater line management control over personnel functions.

Purpose

The intent of this Project is to permit increased line management involvement in major personnel-related decisions, such as recruitment, compensation, training, appraisal, and rewards. The line manager is the primary decision maker on personnel issues of pay, classification, merit, and job assignments which have important effects upon motivation, performance, and organizational effectiveness. To accomplish these changes, the Demo Project includes (1) a more flexible, manageable, and understandable classification system which aggregates several GS grade levels into broad pay bands; (2) a performance appraisal system that links performance goals, compensation, and organizational effectiveness; (3) an expanded application of the CSRA merit pay concept for both supervisory and non-supervisory employees; and (4) an emphasis on performance as a primary criterion in the retention process while retaining tenure, veterans preference, and length-of-service factors.

Types and Number of Participating Employees

In keeping with the 5,000 employee limit in the Project, the two Centers have included the following full-time personnel in the Demo Project:

	NOSC	NWC
Scientists and Engineers, and Senior Professional Staff	1,284	1,444
Technicians	332	586
Administrative Specialists	223	395
Technical Specialists	171	183
Clerical	360	–
	2,370	2,610
	4,980	

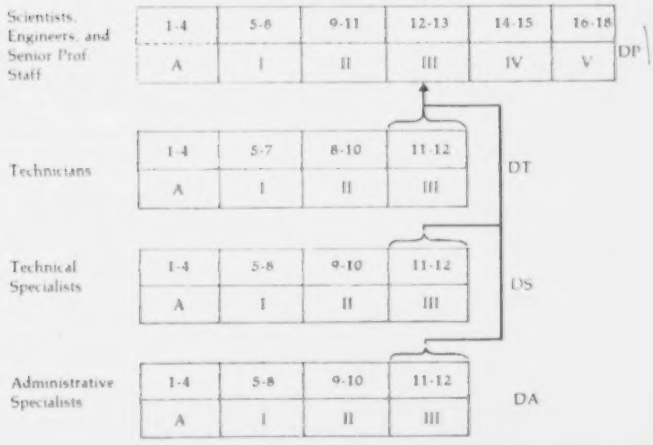
Scientists and engineers and all GS-13-15 personnel entered the Project when it began in July 1980. The GS-12 Administrative and Technical Specialists entered the Project in January 1981 with the Technicians following in August 1981 and the GS-11 and below Administrative and Technical Specialists being included in August 1982.

Since both Centers' clerical population could not be added to the Project without exceeding the 5,000 person limitation, it was decided to include only NOSC's clerical personnel in August 1982, in order to ensure an opportunity for full evaluation of the Project's concepts for all of the above career paths.

Basic Features

Implementation procedures for the Project vary somewhat between the two Centers in relation to unique management needs and styles. However, both Centers have a similar basic approach to pay, performance appraisal, and position classification. Under the experimental effort, both Centers have grouped 16 pay and classification grades (GS-1 through GS-16) into broad levels as noted below for the applicable career path:

Career Path Identification by Classification Level as Related to Current Grade Levels



The separate career paths incorporate at least two grades within each path. Performance appraisal serves as the basis for determining incentive pay adjustments in terms of classification standards and performance objectives established. Each career path is a competitive area for reduction-in-force purposes, and retention is determined primarily on the basis of performance appraisal.

Classification and Pay System

Each class of positions covered by the Demo Project (scientist and engineer, technician, technical specialist, and administrative specialist) reflects career progression of those having similar qualification requirements and lines of work. Pay bands in each career path reflect

entry, trainee, and journeyman levels of work for that occupational group. Series levels are included in the DP career path.

The classification system recognizes both the rank-in-person concept reflecting unique aspects of matrix and line management plus sponsor relationships as well as the rank-in-position distinctions through classification in broad classification levels. The first line supervisor is involved with classifying positions by using simplified standards for each pay level. Typical duties, responsibilities and levels of difficulty of work at each classification level are listed in a "menu" format. Supervisors then select from the appropriate classification standard for a given level. To acknowledge personal contributions and capabilities of individual employees as well as duties and responsibilities of positions, the traditional position description or PD has been retitled "Personal Activities and Capabilities" or PAC. The classification standards are computerized to allow for automatic listing of menu items, and the resulting PAC is identified by special code and stored for record purposes. PACs are quickly prepared and approached with maximum line supervision involvement and provide clear distinctions between functions, specialties and classification levels.

Scientific and engineering salaries are established consistent with labor market conditions and the applicant's experience and education. However, since the basis for the Project pay system is the General Schedule, scientists' and engineers' pay rates for the various levels of responsibility are directly keyed to the special salary rates for scientists and engineers.

Performance Linked Pay

Employees can be paid no less than the minimum pay rate established for the pay band to which assigned. The broad band has been divided into increments between the highest and lowest salary of the level (i.e., GS-12/1—13/10 for DP level III and 24 increments, each equaling approximately 1.5% of the highest salary level). Increases in pay are based on performance within available resources, and the Center's annual merit payout has been approximately 2.4% of Demo Project payroll. This figure has been derived from monies that formerly would have been paid to deserving employees in the form of QSIs, SSPs, and within-level promotions.

Employee performance is evaluated on the basis of five incentive pay groupings from performance that is demonstrably exceptional to that which is substantially below fully successful. The following identifies performance rating definitions and payout choices in terms of whether or not comparability pay (federally determined) and increments are awarded for the various levels of performance indicated.

Performance Ratings/Payout

Rating	*Definition*	*Pay*
1	Performance that is demonstrably exceptional—clearly deserving of recognition equivalent to a within-level promotion.	c + 4i or c + 3i
2	Quality performance that exceeds the fully successful standards.	c + 2i
3	Fully successful performance—meets the expected results of the performance plan. Growth and progression normal for NWC.	c + i or c
4	Below fully successful. Corrective action needed.	c/2
5	Substantially below fully successful. Serious performance deficiencies. Needs significant improvement for work to meet established standards.	0

Employees who exceed performance expectations receive incentive pay increases substantially exceeding government-wide comparability increases. Employees who fully meet performance expectations receive at least comparability, while those who do not fully meet performance expectations receive either one-half or none of the comparability increase.

Employees' salaries advance to the upper limit of a pay bank only through performance, not time-in-level. A lump sum bonus payout, corresponding to the payout shown above, is given to those employees whose salaries are at the top of the level or the pay cap. If, on the other hand, an employee receives no or limited pay increases due to marginal performance, and the minimum salary of the current pay band exceeds the present salary, the employee "migrates downward" to the next lower level. This occurs without specific adverse or performance-based action. In this manner, higher performing employees are rewarded in consonance with their contributions and poorer but minimally adequate performers have their salaries held constant. Employees whose performance is unacceptable may be removed or changed to a lower level as a performance-based or adverse action.

Reduction-in-Force

The Demonstration Project's major change in RIF procedures is the ranking of employees within each competitive level, based primarily on performance rating groupings and secondarily on the elements of tenure, veteran's preference, and length of service. The intent is to increase the probability of retaining the highest performing employees in their positions and displacing the lowest performers. "Bumping" is limited to the career path to which the employee is currently assigned. Thus, if engineering positions are abolished, clerical, technician, specialist and administrative personnel would not be bumped.

Employees can retreat to the career paths through which they progressed. Retention standing within a competitive level is determined by performance rating groups, and the high retention group(s) is placed at the top of the register in standard tenure, veteran's preference, and length of service order. Employees in lower retention groups are

placed at the bottom of the retention register, using the same standard order and are the first to be released from the competitive level. Individuals in higher retention groups always displace those in the lower group(s).

Implementation

A task team approach has been used to develop implementation ideas and create "ownership" of these important changes to the federal personnel system. This has involved representatives of career paths and various skills at the Center who are affected by the Project. Task teams involving pay, classification, performance evaluation, and communication are examples of representative groups from both managers and employees affected by the Project. They have made significant contributions to Center policies affecting all implementation aspects of the Demo-Project. Special employee groups to review provisions affecting career paths, such as technicians, have been used, also. These groups have influenced changes which have been made to pay bands, performance appraisal, and the new position classification approach. Task team policies have been developed in conjunction with NOSC task team counterparts.

As career paths have entered the Project, training has occurred in some depth on the basic features of the new system, how it works, and the responsibilities and expectations of supervisors and employees. Training sessions on performance planning and assessment, compensation, classification, and general system operation have been conducted by employees who have been trained by Personnel Department representatives. Specific topics other than those above included goal setting, motivation, communication, handling conflict, and performance monitoring. Essential to the understanding and acceptance of the Project have been efforts on communication and descriptions of the departmental Performance Review Boards (PRBs) where final performance evaluation decisions for employees are made.

Evaluation

To assess the Project results and evaluate the feasibility of applications to other federal organizations, evaluation efforts by OPM contract and internal evaluation groups at both Centers are underway. Coopers and Lybrand were awarded the OPM contract ($100 K with each Center paying one-fourth of the cost) and will provide their first report in September 1982. This Center's internal evaluation effort is headed by Dr. Ed Alden (Code 08203). The external evaluation effort will monitor the implementation of the Project and assess anticipated and unanticipated effects. The firm fixed price contract is for one year with four renewable options of one year for the five year evaluation period. To help isolate effects of the Project, changes at the two participating Centers will be compared with data from two other Navy labs, NADC and NSWC.

Factors as recruitment success, turnover, and Personnel Department performance will be evaluated, along with management issues of equity, motivation, satisfaction, mobility, line management flexibility/

accountability, and changes in the number of adverse actions. Attitude surveys are being conducted by both the internal and external evaluators, plus management audits, exit interviews, and other analyses involving recruitment, mobility, and sponsor satisfaction. OPM's major objectives for measuring the success of the Project include recruitment success, increased high performer retention, improved personnel function performance, and expanded performance-based pay systemization.

Benefits of Project

The Project is expected to demonstrate that a genuinely management-centered personnel administration process will lead to more efficient and effective use of the resources of the participating laboratories. In addition, by providing a means of real-world testing for models of improved and simplified classification and performance evaluation systems, the project will have results that can be applied throughout the federal service. Some examples of anticipated effects caused by the proposed changes and corresponding measures for evaluating these effects are depicted in Table 1.

Table 1.

Some Examples of Anticipated Effects Caused by the Proposed Changes, With Measures for Evaluating These Effects.

Change	*Anticipated effects*	*Evaluation measures*
Classification and pay	Increased recruitment success	Cost per recruit, recruit quality and quantity
	EEO commitment	Cost, quantity and quality of recruits
	Flexibility of workload assignment	Time, cost of reassignments and transfers
	Increased personnel effectiveness	Cost, management and employee satisfaction
Performance appraisal	Correlation of pay and performance	Perceived equity
	Improved EEO relations	Increased retention of high performance minorities and women
	Increased employee commitment	Satisfaction and commitment instruments
	Decreased turnover of "desirable" employees	Turnover rate of critical employees
	Increased turnover of low performers	Turnover rate
	Increased organizational effectiveness and efficiency	Peer, sponsor, and user evaluations, cost to conduct business
Retention	Retention of high performers	Retention rates
	Increased EEO effectiveness	Retention rates of minorities and women
Adverse action	Increased adverse action effectiveness	Cost, rate of successful actions

Progress Report
ON
Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel

VOLUME I—SUMMARY REPORT

JULY 1984

OFFICE OF SCIENCE AND TECHNOLOGY POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20506

CONTENTS

Volume I: *Summary Report*

Introduction 1
Background 1
Committee on Federal Laboratories 2
Responses to the Recommendations 2
1. Mission 4
2. Resources: Personnel 7
3. Resources: Funding 12
4. Management 16
5. Interaction with Universities, Industry, and Users of Research Results 20
Appendix A: Presidential Memorandum 28
Appendix B: Federal Coordinating Council for Science, Engineering and Technology Federal Laboratory Committee 29

Volume II: *Status Reports By Agencies*

USDA 1
DOC (NBS, NOAA) 7
DOD 17
DOE 25
DHHS (NIH) 31
DOI (USGS, BOM) 37
DOT 44
EPA 50
NASA 55
Acronym Glossary 60

INTRODUCTION

Background

The White House Science Council's Federal Laboratory Review Panel was appointed by Dr. Solomon J. Buchsbaum, Chairman of the Council, in March 1982. The Panel was chaired by Mr. David Packard. Dr. George A. Keyworth, Science Advisor to the President, asked the Panel to review the Federal laboratories and to recommend actions to improve their use and performance. The Panel was specifically charged to look at laboratory missions, identify any systemic impediments to performance, and determine whether this Nation is getting the optimum return on its substantial investment in talent and facilities at the Federal laboratories.

There are more than 700 Federal laboratories, set up at various times for specific purposes. Over time, their activities have tended to expand and diversify, partly because they succeeded in their original tasks and partly because mission requirements changed. In some cases, this expansion has resulted in a dilution and weakening of purpose, mission, and capability.

Today these laboratories account for almost one-third of the Federal Government's annual expenditure for R&D and one-sixth of the total national R&D expenditure. Collectively, they employ almost half a million scientists and engineers. Thus, the Federal laboratories represent a significant fraction of the Nation's total science and technology enterprise.

The Federal Laboratory Review Panel issued its report (generally referred to as the Packard Report) in May 1983.[1] The Panel was convinced that the Federal laboratories have great potential and are an essential part of the American institutions where R&D is performed and where scientists and engineers receive training. At the same time the Panel stated that it had observed a number of serious deficiences that limited both the quality and cost-effectiveness of R&D done by those laboratories.

The Panel made a number of recommendations focused on mission, personnel, funding, management, and interaction of Federal laboratories with universities, industry, and users of research results. In presenting its recommendations the Panel stated: "At a time when the Nation's economic and military competitiveness is increasingly challenged, it is imperative that the Nation gets the optimum return from its investment in the Federal laboratories."

Highlights of the report were briefed to the President in July 1983. In August 1983 the President directed that the Office of Science and Technology Policy and the Office of Management and Budget lead an interagency effort to respond to the central thrust of the report's recommendations.[2]

---

[1] Report of the White House Science Council, Federal Laboratory Review Panel. Office of Science & Technology Policy, Executive Office of the President, 1983.
[2] See Appendix A for Presidential memorandum.

Committee on Federal Laboratories

In response to the President's August 1983 memorandum, the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) established a Committee on Federal Laboratories[3] to monitor implementation of the White House Science Council's recommendations. The Committee first met in October 1983 and established four working groups to monitor progress and coordinate joint action where necessary. These working groups were organized by topical areas covered in the Science Council's report, as follows:

- Mission and Management
- Personnel
- Funding
- External Interactions

The chairmen of these working groups and the chairman of the Committee worked closely to eliminate gaps and overlaps.

Although the charter of the Committee on Federal Laboratories expires on July 1, 1984, when the progress report is due to the President, it was the consensus of the Committee that the charter should be extended to allow continuation of periodic meetings to discuss mutual problems. There is also a need to continue the momentum established in responding to the Science Council's report.

Responses to the Recommendations

The President's interest in the health of Federal laboratories has caused the Packard Report to receive top management attention in the Federal agencies. In general, the agencies have been very responsive in implementing the White House Science Council's recommendations, especially when the agency head has been directly involved. Perhaps the most pervasive impact of the Science Council's report has been a heightened awareness on the part of top management in Federal agencies of the need to focus on laboratories, in terms of both their output and their institutional needs. The appropriate management attention has brought about, and will continue to bring about, a variety of improvements.

The recommendations addressed all Federal laboratories and necessarily had to deal for the most part with norms rather than specific institutions or agencies. Consequently, the responses varied from agency to agency, depending on a variety of factors. In no case did an agency disagree with the merit of the management principles or the spirit of the recommendations. The differences in degree of implementation reflect that: (1) some agencies had internal parallel studies under way and began early to effect management improvements once the Packard Report was published; (2) others had completed major related actions a few months prior to the report; and (3) some view their existing processes as already highly consistent with many of the recommendations.

---

[3]See Appendix B for a list of Committee members.

The most difficult recommendations to implement are those involving the legislative process: creating a separate scientific/technical personnel system and instituting multiyear funding for R&D. Since they affect almost all Federal agencies involved in R&D, they are being handled jointly on a government-wide basis.

In the chapters that follow, the recommendations are discussed in the same order and groupings as they appear in the White House Science Council's report. Progress on each recommendation is summarized and, where applicable, selected agency accomplishments are presented as examples. Finally, a discussion of future directions summarizes recommendations for follow-on efforts.

1. MISSION

DEFINITION OF MISSION

Recommendation 1-1: As a top management priority, Federal agencies should re-examine the missions of their laboratories with the laboratory directors. The agencies should redefine the missions as necessary to ensure that they are consistent with the appropriate roles for Federal laboratories. The missions must be made sufficiently clear and specific to guide the agencies and the laboratories in setting the goals against which the laboratories' performance can be measured.

PROGRESS SUMMARY

Defining the mission of the laboratories is a difficult task requiring that the agency's mission is clear and that the laboratories receive adequate attention from top management. Some of the agencies and laboratories have missions defined by their statutes (e.g., the National Institutes of Health and the National Bureau of Standards) and believe that unclear mission is not a problem.

All agencies made an effort to implement this recommendation. Most have existing procedures for reviewing their activities, and the report's recommendations were considered in the review processes. Several agencies took additional measures specifically to implement the recommendations.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- The Agricultural Research Service (ARS) developed a long-term research plan identifying areas for increased emphasis for the 1980s as well as research possibilities for the next 20 to 50 years. Such long-term planning had been lacking before. The plan reflects the best thinking of some 500 ARS scientists and members of its National Planning Staff on how ARS can meet the USDA's short- and long-term needs most effectively and efficiently. It will serve to guide the missions and performance evaluation of the ARS laboratories.
- The Administrator of the National Oceanographic and Atmospheric Administration (NOAA) had the mission statements of all the NOAA laboratories and Fisheries Centers revised and updated in response to the report.
- In July 1983, the Secretary of Energy issued the Department's policy guidance on the role and missions of the multiprogram laboratories consistent with the National Energy Policy Plan. In February 1984, the Department of Energy's Laboratory Management Council developed a generic laboratory role statement and reviewed and revised all proposed laboratory mission statements. An established institutional planning process will ensure annual review of laboratory missions projected 5 years into the future.

- The Secretary of Transportation appointed a new Science and Technology Advisor for the Department and directed him to oversee implementation of the report. The operating administrations have evaluated laboratory operations and are instituting changes necessary to ensure consistency with new laboratory mission statements and performance goals. The Department recently completed a study that identified various options for privatizing operation of the Transportation System Center. Discussions on the practicability of these options are ongoing.
- In addition to continually reviewing and revising the mission of its laboratories, the Environmental Protection Agency's Office of Research and Development plans to establish a Strategic Planning Staff whose function will be to study emerging environmental problems and determine: (1) whether research is warranted, (2) where research efforts should be focused, and (3) perhaps even how the research results would relate to current or proposed policy direction. The laboratories' missions will be redefined as necessary to accommodate the research efforts identified by the Strategic Planning Staff.

FUTURE DIRECTIONS

While direct agency response to this recommendation has been good, there obviously is a need to continually re-examine the laboratories' missions. Such activities should be carried out in conjunction with the oversight function discussed under Recommendation 4-1.

SIZE OF LABORATORIES

Recommendation 1-2: The size of each Federal laboratory should be determined by its missions and the quality of its work. That size should be allowed to increase or decrease (to zero, if necessary) depending on mission requirements, but it should not fluctuate randomly. Preservation of the laboratory is not a mission.

PROGRESS SUMMARY

The Panel did not expect that special and immediate actions be taken to implement this recommendation. The agencies have mechanisms established for reviewing the staffing of the laboratories. These reviews have taken place in conjunction with the agencies' annual budget review, which is an acceptable approach as long as the budget allocation reflects careful evaluation of the agencies' missions and performance.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- Recent mission redefinitions in the Department of Energy have resulted in significant decreases in laboratory size in the area of applied technologies, particularly those viewed as having near-term commercial benefits. The Laboratory Management Council, as part of its evaluation of laboratory 5-year institutional plans, will review the proposed size of laboratories based on approved missions.

- In the Department of Transportation, the Federal Aviation Administration's Technical Center has reduced functions not considered essential to the National Airspace System Plan and increased its staffing for testing and evaluation of new computers and automated systems, consistent with the plan. Changes in Administration priorities have also been reflected in the staffing levels and skill mix of the Transportation System Center. The Transportation Test Center of the Federal Railroad Administration has been operated for several years by the private sector; its operators are free to implement staffing adjustments based on anticipated mission requirements.

FUTURE DIRECTIONS

Linking laboratory staffing review to budget reviews assures that the size of the laboratories is re-examined annually. However, it does not assure that this size reflects the missions of the laboratories or the quality of their work, particularly in times of prosperity. The agencies must continue to focus on laboratory missions and quality of work rather than size of the budget. There will always remain external factors affecting laboratory staffing. Also, the creation of new laboratories has not always been based on the agency's determination of need. Decisions to close or consolidate laboratories have been politically difficult and will likely remain so.

2. RESOURCES: PERSONNEL

SCIENTIFIC/TECHNICAL PERSONNEL SYSTEM

Recommendation 2-1: Administrative and legislative actions should be initiated now to create, at government-operated laboratories, a scientific/technical personnel system that is independent of current Civil Service personnel systems. The experimental system for managing scientific and technical personnel at the Naval Weapons Center and Naval Ocean Systems Center is an example of how this can be approached.

PROGRESS SUMMARY

Since this recommendation applies to all agencies with R&D activities, and proposed legislation requires coordination across these agencies, the working group on personnel issues approached it as a joint effort rather than on an agency-by-agency basis. The major achievements of the working group are:

- Development of model legislation;
- Assessment of actions that could and should be taken that do not require legislation;
- An examination of the government-owned, contractor-operated (GOCO) laboratory modus operandi based on the Department of Energy's experience with the GOCO concept; and
- Collection of appropriate statistical information

The proposed legislation is undergoing review at senior levels in the agencies and in the Office of Personnel Management. Actions that do not require legislation have been recommended by the working group and are under consideration by the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB). Examination of the GOCO option is provided as an alternative to operating the laboratories with Federal Government employees.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- *Key features of draft model personnel legislation.* The legislative model produced by the interagency working group embodies the following concepts:
  - —Permits agencies to establish alternative personnel systems;
  - —Applies to scientific and technical personnel in the Federal laboratories, and to similar personnel throughout an agency if broader coverage is deemed essential to mission accomplishment;
  - —Bases pay on performance rather than on longevity;
  - —Creates broad pay bands;
  - —Simplifies job classification;

—Allows the pay cap to be waived for up to 5% of the covered positions—these uncapped positions are limited to specially qualified scientific and technical personnel;

—Permits the agency head to classify positions and fix compensation so as to make positions competitive with rates and practices for comparable positions outside of the Federal Government;

—Allows the inclusion of positions now in the Senior Executive Service (SES); and

—Permits the Naval Weapons Center and Naval Ocean Systems Center personnel systems to become permanent.

The draft model legislation does not describe a personnel system in great detail. It provides some general guidelines. In spirit, the model legislation is very similar to the demonstration project section (5 USC 4703) of the Civil Service Reform Act of 1978. The model legislation provides the Office of Personnel Management (OPM) and the agencies the authority to develop alternate personnel systems for scientific and technical personnel at Federal laboratories and, under appropriate conditions, outside of Federal laboratories. These systems can be tailored to the peculiar needs of a given agency or of a given laboratory. It is anticipated that any changes in agency personnel systems would be accomplished, over time, within existing budget resources and be the basis for improving the use of those resources.

- *Personnel actions not requiring legislation.* A number of actions were also considered within existing statutory authority to improve the ability of government-operated laboratories to attract, retain, and motivate scientific and technical personnel. Actions recommended by the interagency working group are:

—Exclude laboratories from the current proposal to reduce the number of employees in Civil Service grades 11 through 15; the technical work of the laboratories is performed almost entirely by personnel in grades 11 through 15, and entry into, and promotion within, these grades should be facilitated, not impeded;

—Allocate to the laboratories more positions for specially qualified scientific and technical personnel under provisions of 5 USC 3104, and allow some supervisory responsibility for such positions;

—Provide government-operated laboratories with blanket, permanent direct hire authority for all professional scientific and technical positions in the laboratories;

—Provide government-operated laboratories with blanket, direct hire Excepted Service Appointment Authority for research associates;

—Exempt laboratory summer hires in technical positions from manpower ceilings in order to bring in new ideas and provide a source of potential recruits for laboratory staff positions;

—Include special rate schedules, for engineers and other manpower shortage occupations, in annual cost of living adjustments that are applied to other Federal pay scales; and

—Increase the probationary period for scientific and technical personnel from one year to a more suitable period, such as 3 years.

FUTURE DIRECTIONS

Further consideration of the draft model legislation as a basis for legislation that might be recommended by the Administration needs to reflect the official views of the Office of Personnel Management and the heads of the affected departments and agencies. The appropriate next step would be for OPM to consider the proposed model legislation and, if it concurs, to submit a proposed bill to the Office of Management and Budget for legislative clearance by the affected agencies. This process should be completed by the beginning of the next Congress.

Actions not requiring legislation can be given further consideration by OPM for agency and OMB/Office of Science and Technology Policy review while the model legislation discussed above is under review.

Both legislative and administrative changes in personnel systems for agency laboratories operated with Federal employees will need to be assessed in the review process in light of:

- The extent of the problems faced by the laboratories and the potential impact of changes;
- The effect of special treatment of laboratory personnel on the Civil Service system in general; and
- The impact of legislation and administrative changes on broader Administration efforts to restrict overall Federal employment, to hold down average grades, etc.

SALARY ADMINISTRATION AT CONTRACTOR-OPERATED LABORATORIES

Recommendation 2-2: Contracts governing government-owned, contractor-operated laboratories should be rewritten to permit the contractor to establish and carry out an independent salary administration.

PROGRESS SUMMARY

The Air Force contract with the Massachusetts Institute of Technology does permit the university to establish and carry out an independent salary administration at Lincoln Laboratory. For salaries subject to Department approval, the Department of Energy (DOE) has increased the salary cap on the directors of GOCO laboratories. At the present time, applicable salary actions in excess of $50,000 still require DOE approval. In the case of the Jet Propulsion Laboratory, the National Aeronautics and Space Administration (NASA) reviews annually the average salaries for various categories of employees. DOE and NASA do not require prior approval of GOCO laboratory job offers.

FUTURE DIRECTIONS

DOE is increasing the threshold for salary approvals by $10,000, where applicable, and thereby delegating approval authority to the laboratories for salaries up to $60,000. DOE will review periodically the threshold levels to

ensure that there is no increase in the percentage of total salary actions reviewed by the Department. DOE will also continue to refine and clarify criteria for market basing of salary structures to facilitate the review and approval of periodic salary adjustments with only minimal discussions with the Department.

CONTROL OF MANPOWER LEVELS

Recommendation 2-3: Personnel ceilings at government-operated laboratories should not be used in addition to budgetary control. Federal agencies should provide budget constraints and give the laboratory directors freedom to decide how to meet them. Laboratory directors should also be allowed to make the final decisions on contracting for support services at the laboratories.

PROGRESS SUMMARY

The situation is quite mixed across the government. Most Federally operated laboratories find themselves under some form of personnel ceilings in addition to fiscal constraints. To remain within necessary overall limits on Federal manpower for an entire agency, and to properly carry out responsibilities for overall agency management, agency heads often find it necessary to allocate specific manpower resource levels to subordinate laboratories. In some cases, the personnel ceilings are on the total laboratory population. In other cases, the total number of high grades (GS-13 through 15) have been under a separate ceiling. At times, laboratories have found themselves simultaneously under all of the above constraints. There has been a growing awareness within the Federal agencies that these multiple constraints result in lack of flexibility and the creation of non-productive bureaucratic processes. The final result is often a workforce that is not optimum for the current mission of the laboratory. There is a need, therefore, to strive for a better balance between the controls necessary for agency heads to meet their responsibilities for overall agency management and a Federal laboratory director's need for sufficient flexibility to permit optimum laboratory management.

The Department of Defense industrially funded laboratories are no longer operating under total personnel ceiling control. Other DOD activities and other agencies currently are operating under some form of total ceiling control.

The April 1984 report of the House Armed Services Committee on the Department of Defense Authorization Act, 1985, recommends waiver of civilian personnel ceilings for fiscal year 1985. The report states: "The Committee was greatly encouraged by the results of the industrial fund test. Facing a total workload that was little changed from 1982, industrial fund managers did not significantly expand the overall work force in fiscal year 1983. Thus the most important result of the test is what did not happen—managers, unconstrained by ceilings, did not engage in unwarranted hiring." (p. 246)

FUTURE DIRECTIONS

On the assumption that personnel ceilings for agencies will need to be retained to meet overall Federal employment goals of the Administration, agency heads should allow maximum flexibility to laboratory directors in the control of staffing at laboratories, including the use of contract support personnel.

3. RESOURCES: FUNDING

MULTIYEAR FUNDING FOR R&D

Recommendation 3-1: The Congress and Office of Management and Budget should authorize funding for R&D programs on a predictable multiyear basis so that staffing levels and research activities at Federal laboratories can be properly planned.

PROGRESS SUMMARY

An interagency working group addressed this recommendation as a joint issue since it involved almost all agencies. When the working group examined trends in R&D funding at the agency level, it found that for both basic and applied research, funding is surprisingly stable for most agencies and has shown a steady increase in the past years. However, when agency funding is disaggregated and examined at the component and laboratory level, the fluctuations are larger. In the views of the working group, major factors contributing to these fluctuations are:

- Late Congressional appropriations and agency reviews, and reprogramming actions that cause uncertainty until late in the fiscal year;
- Congressional and Administration changes in focus and areas of interest;
- Continuing resolution authority in lieu of Congressional appropriations; and
- Unpredictable Federal civilian pay raises that have to be paid for out of R&D funds.

Thus, agency operating procedures as well as the appropriation process require modification in order to implement this recommendation.

The interagency working group on funding believes that the Packard Report recommendation can best be implemented if funding for R&D is appropriated on a 2-year basis.

FUTURE DIRECTIONS

Where appropriate, the Administration should encourage Congressional interest in, and actions to provide for, multiyear authorizations and appropriations for R&D programs. In addition, agencies should review their own operating procedures to minimize internally generated uncertainties in funding laboratories.

While improvements in funding and personnel planning and management are the focus of Packard Report recommendations, future thrusts must also include upgrading laboratory facilities and equipment as an appropriate trade-off against operating funds within total available funds. Continuous, rapid changes in the state-of-the-art make it essential that Federal laboratories be equipped with modern buildings and tools.

DISCRETIONARY FUNDS

Recommendation 3-2: At least 5 percent, and up to 10 percent, of the annual funding of the Federal laboratories should be devoted to programs of independent research and development at the laboratory directors' discretion. Federal agencies should establish a mechanism to evaluate the results of such work, with the size and continuation of discretionary funds related to laboratory performance. In order to encourage cooperative research programs, the laboratory directors should have the authority, and be encouraged, to spend part of the discretionary funds at appropriate universities and industries.

PROGRESS SUMMARY

Most agencies reviewed have a discretionary funding program in effect or will institute such a program in the near future. Current status of discretionary funding is:

Agency	*Status*	*Planned Action*
USDA	No explicit discretionary funds	Will establish guidelines to meet recommendation's intent
DOC/NBS	About 6%	None
DOC/NOAA	No explicit discretionary funds	Discretionary funds will be requested as part of future budget initiatives
DOD/Army	10% of basic research None for applied research	None
DOD/Navy	7% of basic research 2% of applied research	Increase to 5% of applied research
DOD/Air Force	7% of basic research None for applied research	Begin 0.5% of applied research in FY 85. Increase to 4% by FY 89
DOE	Up to about 5% in addition to significant flexibility	Implementation of new policy statement with emphasis on results-oriented review
HHS/NIH	All funds considered discretionary	None
DOI/BOM	No explicit discretionary funds	None
DOI/USGS	5-10%	None
DOT	No specific percentage used as guidelines. New policy being reviewed	Policy supporting the recommendation planned for next budget cycle
EPA	No explicit discretionary funds	Laboratory directors will be given greater flexibility in conducting projects
NASA	About 4% excluding salaries	None

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- The Office of Naval Research has agreed to maintain discretionary funds as a constant percentage of basic research funds (about 7%). The Office of Naval Technology has agreed to increase the percentage of discretionary funds as a part of applied research funds (from 2% to about 5%).

- The Air Force currently maintains discretionary funds in basic research equal to 7% of basic research budget. In fiscal year 1985 the Air Force will establish applied research discretionary funds equal to 1/2% of applied research budget, growing to 4% of applied research in fiscal year 1989.
- The Department of Energy issued a policy statement in December 1983 that clearly established policy and uniform guidelines for use of exploratory research and development funds at multiprogram laboratories. Under this policy, laboratories may use a reasonable amount of operating funds for early explorations and exploitation of creative and innovative scientific and technological concepts arising in the course of the laboratory's work. The laboratory directors exercise authority in choosing projects for funding.

FUTURE DIRECTIONS

Where providing more discretionary funds comes as a new concept, and where such funds are in constant competition with directed funding, agencies need to be continually aware of the need to foster independent research, consistent with established overall agency roles and missions, as a means of stimulating innovation.

CARRYOVER FUNDING

Recommendation 3-3: Federal laboratories should be allowed to carry forward remaining funds into the next fiscal year. This would eliminate the wasteful practice of hurried spending at the end of each fiscal year.

PROGRESS SUMMARY

There is a wide variation among agencies in the length of time allowed for obligation of R&D funds. The current status is:

Agency	*Obligation Authority Time Limit*
USDA	1 year
DOC	No time limit
DOD	2 years
DOE	No time limit on R&D appropriations
HHS/NIH	1 year
DOI/BOM	No time limit on research funds
DOI/USGS	1 year
DOT	No time limit
EPA	2 years
NASA	2 years

While the Department of Defense (DOD) has 2-year obligation authority from Congress, agency policy requires that laboratory directors obligate up to 97% of their budgets by the end of the first fiscal year and 100% by the end of the following quarter. Difficulties arising from this approach are further compli-

cated when appropriation action is delayed beyond the start of the fiscal year. No action has been taken by DOD to modify the policy. There are no plans at present on the part of agencies with 1-year authority to ask Congress for more flexibility.

FUTURE DIRECTIONS

Where agency policies cause inflexibility and inefficiencies in the obligation of laboratory funds, the responsible R&D managers must take the initiative in making reforms. Agencies with only 1-year obligation authority must likewise take the initiative in their budget proposals to request a longer period.

4. MANAGEMENT

OVERSIGHT OF LABORATORIES

Recommendation 4-1: For each Federal laboratory, there should be an oversight function responsible for assuring the continuing excellence of the laboratory. This function could be performed by an external committee which should include strong industry and university representation. This committee would spend enough time at the laboratory to become familiar with the laboratory's strengths and weaknesses. It would focus on productivity and on the excellence, relevance, and appropriateness of research. The oversight committee would make recommendations to the agency and inform the laboratory director of these recommendations. Those recommendations would be taken into account by the agency and laboratory in their budget decisions. In addition, the committee would give special attention to reducing micromanagement by the sponsoring agency.

PROGRESS SUMMARY

The Packard Panel did not intend to dictate a single form of oversight for all laboratories in all agencies. The important features sought of this oversight are that (1) it provide a broad, laboratory-wide evaluation, (2) this evaluation go beyond the scientific merit of individual research areas, as is usually the case, to cover the appropriateness of the laboratory work and the management of the laboratory, and (3) the oversight body report to the parent agency rather than the laboratory director alone. Most of the agencies have existing oversight mechanisms that could fulfill the above expectations.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- The National Oceanographic and Atmospheric Administration plans to establish an Advisory Group for the oceanic and atmospheric research laboratories, reporting to the Oceanic and Atmospheric Research Assistant Administrator.
- At the Department of Defense, the Services were requested to form external advisory groups for their laboratories under the aegis of their Scientific Advisory Boards and to provide plans for how these groups would operate to perform the oversight functions. These plans have been submitted to the Secretary of Defense.
- The Army Materiel Development and Readiness Command has initiated an independent assessment of its laboratories using members of the Army Science Board. Peer reviews are to be completed in 1984 at the Army Tank-Automotive Command and at the Army Avionics Research and Development Activity. This peer review process will be institutionalized to cover 4 to 5 laboratories per year. The assessments, scheduled for 3 to 5 days at each laboratory, will review the quality of the staff, facility, and technical program; examine how productive the laboratory is

in accomplishing its mission; and assess how relevant the laboratory's work is to key Army problems.

- The Department of Energy's (DOE's) Laboratory Management Council is working on ways to implement effectively the oversight function appropriate to each laboratory's circumstance, utilizing existing organizations and boards where effective, and modifying processes where necessary. Oversight panels exist for Argonne National Laboratory and Brookhaven National Laboratory; the new Oak Ridge National Laboratory contract includes a provision for an oversight panel. Weapons laboratories have similar panels reporting to the University of California. Plans are being developed to ensure that these groups can and will effectively perform the required oversight functions.

FUTURE DIRECTIONS

Agencies that have not yet established oversight mechanisms need to continue movement in this direction. There are a number of successful models that can be emulated.

COMPETITIVE PEER REVIEW FOR FUNDING LABORATORY BASIC RESEARCH

Recommendation 4-2: Federal agencies should rely to a greater extent on the competitive peer review process for funding basic research at their laboratories.

PROGRESS SUMMARY

Some form of peer review takes place at most laboratories. Additional actions are under way in several agencies to respond to this recommendation.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- The Department of Energy's proposal preparation and approval process within the laboratories has many features comparable to traditional peer review, including extensive review by advisory committees to the laboratories. In addition, DOE has established a working group to propose guidance on how best to accomplish competitive peer review of basic research performed by the laboratories and by universities. The Laboratory Management Council will review the proposed actions and recommend any necessary changes in Departmental policy.

FUTURE DIRECTIONS

The concept of peer review is becoming more widely accepted as a form of competition and quality control. Agencies that have long-established peer review systems must re-examine them periodically to ensure that they are functioning effectively.

APPOINTMENT AND EVALUATION OF LABORATORY DIRECTORS

Recommendation 4-3: The laboratory director must be held accountable for the quality, relevance, and productivity of the laboratory. Appointment of the director should be for a finite term, with the option of extending or abbreviating the term depending on the performance of the director and the laboratory.

PROGRESS SUMMARY

Most of the agencies have government-operated laboratories whose directors are members of the Senior Executive Service (SES). The military directors of the Department of Defense laboratories have 3-year terms. The agencies feel that the SES system provides them with sufficient flexibility. DOE, which principally utilizes GOCO laboratories, has taken action in this area.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- A DOE Order on uniform laboratory appraisal, issued in October 1983, requires annual results-oriented appraisals at all the major multiprogram laboratories, including laboratory director accountability.
- At the National Institutes of Health, a new proposed pay and personnel system recommends renewable terms for laboratory and branch chiefs (5-year terms; after age 70, 1-year terms). One of the institutes has already implemented a policy of appointing new laboratory/branch chiefs to 7-year terms.

FUTURE DIRECTIONS

Even where laboratory directors are in the Senior Executive Service and subject to annual performance appraisals, agencies are beginning to recognize the advantages of having fixed-term appointments. Such appointments establish a planning and performance framework that benefits both the laboratory director and parent agency. Indications are that further progress in the spirit of this recommendation will be made.

REPORTING TO CONGRESS

Recommendation 4-4: The above recommendations apply to all Federal agencies. The management of the Department of Energy presents an additional special problem, and the Panel recommends that the Administration and Congress work together to stabilize and strengthen DOE management and to define and affirm its mission. Congress should also refocus its oversight of DOE R&D into a significantly smaller number of committees.

PROGRESS SUMMARY

Compared to other departments, DOE has undergone the most changes in missions in the past 5 years, evolving from the Atomic Energy Commission to the Energy Research and Development Administration/Federal Energy Ad-

ministration to DOE. Recent reductions in near-term renewable energy, and demonstration and commercialization activities, coupled with the Secretary of Energy's statement on Federal and DOE laboratories' roles, have put the Department in the best position to date to communicate and affirm DOE missions and to participate in discussions with Congress regarding simplifying or refocusing legislative oversight of the Department's research and development.

5. INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

ACCESS TO FEDERAL LABORATORIES

Recommendation 5-1: Federal laboratories should encourage much more access to their facilities by universities and industry.

PROGRESS SUMMARY

Implementation has been strong and widespread. Some Federal laboratories have a long tradition of providing access to their facilities and have already compiled an outstanding record of achievement. Many others are displaying a renewed commitment to this goal and are making good progress toward attaining their individual objectives. A primary reason for this progress is the fact that provision of access to facilities lies almost entirely within the jurisdiction and the means of the laboratories themselves.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- *New construction of joint facilities.* The Department of Commerce's National Bureau of Standards has teamed with the University of Maryland and the Montgomery County Government to form the Center for Advanced Research in Biotechnology. Scientists from academia, industry, and government will conduct joint research in this laboratory to be built by Montgomery County on land donated by a private foundation. The Department of Agriculture's Beltsville Agricultural Research Center will also participate in research at the Center.
- *Support to education.* The Department of Defense (DOD)-sponsored High School Science and Engineering Apprenticeship program has, over the past 4 years, given more than 2,000 young people the opportunity for summer research in DOD laboratories or with university researchers under contract to DOD. Summer research programs in DOD laboratories support approximately 50 graduate students and 300 university faculty members each year. In 1984, DOD will test a new program to give summer research experiences to high school teachers of science and mathematics.
- *Facilities directory.* A "User's Guide to Department of Energy (DOE) Facilities" was published in January 1984 to provide information about unique laboratory facilities and equipment available to industry and universities for conducting their own research on-site at the laboratories using equipment available only at DOE laboratories. In addition, about 5,000 students and university faculty will participate in DOE-sponsored research and training programs at the laboratories in 1984.
- *Facilities for advanced training.* In collaboration with The Johns Hopkins University, the Foundation for Advanced Education in the Sciences at the National Institutes of Health supports a program that permits Ph.D.

students enrolled at Johns Hopkins to carry out advanced thesis research under NIH supervision.

- *Interaction with universities.* The Department of the Interior maintains strong, two-way ties with universities through the U.S. Geological Survey (USGS) and the Bureau of Mines (BOM). USGS graduate internships are awarded to some 30 research students yearly, and over 50 USGS scientists serve as adjunct professors at universities around the country. Most BOM laboratories are located close to university campuses; cooperative agreements are in effect with seven universities for fellowships or for the sharing of facilities. Plans are now under way for a USGS lecture program at historically Black colleges and universities. In the Department of Commerce, the National Oceanic and Atmospheric Administration's (NOAA's) Environmental Research Laboratories and Fisheries Centers are located on or near campuses of major universities. Long-term agreements in the form of cooperative institutes have been established between NOAA and several of these universities.

- *Space Shuttle launches as forum for education.* The National Aeronautics and Space Administration (NASA) has supported five conferences for "Distinguished Educators" at Shuttle launches, each targeted at specific segments of the educational community offering high-impact opportunities. These include women and minorities, science and technology, elementary education, and physics training. The conferences provide curriculum supplements and skills development for elementary and secondary school teachers and university faculty.

- *Visiting scientist programs.* In addition to on-going activities aimed at encouraging university and industry access to their facilities, the Environmental Protection Agency (EPA) recently implemented a new "Senior Visiting Scientists" program. This program is designed to bring some of the leading names in environmental science from universities and other institutions into EPA laboratories to conduct research. These scientists will help promote those areas of environmental science that are most significant to the Agency, and the program will help build closer working relationships between EPA laboratories and leading environmental scientists. At the Department of Commerce, a substantial number of leading senior scientists are also brought into NOAA's research activities.

FUTURE DIRECTIONS

While there is much ongoing activity and a heightened awareness of the need for more access to Federal laboratory facilities by universities and industry, more can be done. Specific recommendations for further action within overall agency manpower ceilings and budgetary constraints are:

- Seek ways to expand current programs that provide students and faculty with opportunities to work in Federal laboratories, particularly cooperative job programs and summer jobs for high school and college students;

- Expand current programs aimed at increasing interchanges among university and laboratory personnel, especially those that bring career laboratory staff to university and other educational environments; and

- Consider legislative action to permit continuity of pension plans for scientists and engineers who move between Federal laboratories and universities.

R&D INTERACTIONS

Recommendation 5-2: R&D interactions between Federal laboratories and industry should be greatly increased by more exchange of knowledge and personnel, collaborative projects, and industry funding of laboratory work, provided an oversight mechanism is established to prevent unfair competitive practices.

PROGRESS SUMMARY

Many instances of technology transfer from Federal laboratories to industry already exist, and some of them are crucial components of national technology, contributing positively to our international balance of payments. On the other hand, more can and should be done in this area. Progress toward promoting more R&D interaction with industry has been less apparent and more uneven than in the case of providing greater access to laboratory facilities. However, implementation of Recommendation 5-2 has been impeded by substantive legal and policy issues lying outside laboratory jurisdiction and control, such as government patent policy and the details of enabling legislation. Many such issues are now being addressed by the Department of Commerce, which has lead responsibility for implementation of the Stevenson-Wydler Technology Innovation Act of 1980. Additional helpful proposals have been prepared by the Department of Energy in response to the 1982 study of DOE multiprogram laboratories by the Energy Research Advisory Board. These two developments, together with the influence of the Packard Report, have produced a renewed commitment by Federal laboratories to help increase our industrial competitiveness.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- *Private sector utilization of DOD-developed equipment.* In May 1984, the Assistant Secretary of the Army for Research, Development and Acquisition signed landmark licensing agreements with two industrial corporations to manufacture products developed by in-house research programs at the U.S. Army Construction Engineering Research Laboratory. The two products, a ceramic anode used in corrosion protection and a weld quality monitor, are not military-unique hardware but have wide application in the construction field. The licensing agreement provides for commercialization of the products, with royalties paid to the Government for sales to the private sector.
- *Improving technology transfer mechanisms.* One of the more effective technology transfer mechanisms is the use of person-to-person interactions. In this way, the knowledge of scientists, engineers, and inventors about products and processes is directly coupled to individuals in other sectors of the economy whose skills and interest lie in the development of those products and processes for the marketplace. Involvement by labo-

57-279 O - 87 - 57

ratory staff members is not only a means of implementing this principle, but it can also contribute to professional development of the individuals involved. The Department of Energy has informed the directors of its multiprogram laboratories that the Department's policy is to encourage technology transfer, consulting arrangements between laboratory employees and the private sector, and improved relations with industry. To facilitate these efforts, DOE has issued a class patent waiver policy for inventions arising from reimbursable work for others and for work at DOE user facilities.

- *Speeding delivery of research discoveries to users.* The Department of Agriculture is implementing a new plan for technology transfer that involves a newly appointed national technology transfer coordinator and a nationwide computer network. The network will transmit current research information from Federally sponsored researchers to computer terminals at land-grant universities and other users in all 50 states.

- *Expanding interaction with industry.* The National Bureau of Standards plans to double (to about 200) the number of industrial research associates working in its laboratories. Additional collaborations with industry include automated manufacturing, electronics, computer standards, and several projects in materials science. A proposal to upgrade the research reactor includes dedicating one-third of the new ports to industrial use. The Bureau received approval from the Department of Commerce in May 1984 to allow use of selected facilities by the private sector for proprietary research.

- *Sharing of health-care technology with industry.* The National Institutes of Health have formed a Committee on Joint NIH-Private Sector Endeavors to promote collaboration with commercial organizations and speed two-way technology transfer. Through July 1983, some 54 non-exclusive licenses and an additional 10 exclusive licenses were granted to industry for patented inventions made in NIH laboratories. Conversely, a recent agreement between the National Cancer Institute and an industrial biotechnology firm will permit NCI to explore industrially developed technology in Federal cancer research programs.

- *Federal technology for pollution control.* The Environmental Protection Agency has established collaborative programs with industry as a major component of the EPA research program to develop pollution-control systems. The products produced by this government-industry partnership include fabric filters, limestone injection scrubbers, sequencing batch reactors, mobile waste treatment facilities, and hazardous-waste disposal techniques.

- *Increasing the availability of data to industry and the public.* NOAA's Space Environment Research Laboratory has recently initiated a contract with a private company to provide real-time solar data and forecasts to the public over WEST STAR 4 satellites. Doppler radar and lightning information gathered by the National Severe Storms Laboratory is being sent in real time via the National Weather Service to local broadcasters.

- *Development and application of carbon-fiber composite materials to replace aluminum in aircraft.* NASA laboratories were instrumental in

developing carbon-fiber composite materials, offering direction-tailored strength equal to that of aluminum at less weight, for flight-critical components of commercial aircraft designs. Three major aerospace firms participate with the NASA laboratories in continuing refinements of this technology and will validate its use for very large wing-box and fuselage structures this year. Several general-aviation aircraft incorporating this technology should attain Federal Aviation Administration flight worthiness certification in 1985.

FUTURE DIRECTIONS

The varied origins and missions of the laboratories have resulted in different degrees of involvement with industry. In some cases, close collaboration with industry has always been part of day-to-day operations. In others, it is a fairly new concept, and some deep-seated institutional attitudes need to be modified. Further actions that need to be taken, for example, are:

- Where it is not stated explicitly, incorporate contribution to U.S. industrial competitiveness as a laboratory mission;
- Formalize the authority of laboratories to enter into cooperative research projects with industry, universities, and non-profit organizations;
- Extend the authority of government-operated laboratories to grant patent rights to private sector organizations in order to encourage external cooperation in Federal laboratory research;
- Establish guidelines for Federal laboratories concerning technology transfer to foreign organizations; and
- Maintain focus on R&D appropriate for Federal support so as to not overtake the role of the private sector in pursuing commercial opportunities created by Federally sponsored research.

FEDERAL PROCUREMENT PROCEDURES

Recommendation 5-3: Contracting by agencies and laboratories for universities and industry to conduct R&D should be encouraged by simplifying the necessary Federal procurement procedures. The procurement process should give laboratory directors greater flexibility in contracting.

PROGRESS SUMMARY

Only limited progress has been made by individual laboratories in implementing this recommendation, since revision of Federal procurement procedures lies almost completely beyond the control of the laboratories themselves and largely beyond the control of entire agencies. The time required to award a contract for basic research continues to increase in most agencies. The remedial action required is government-wide in scope, and enormously complex. Fortunately, there is promise of improvement in response to recommendations of a November 1983 report of the National Academy of Public Administration (*Revitalizing Federal Management: Managers and Their Overburdened Systems*, Chapter 4). These recommenda-

tions are widely supported by Federal procurement executives and appear to offer the best available approach to continued, systematic progress in this area.

Achieving a procurement policy that is both equitable and efficient requires a balance between measures to ensure adequate competition and procedures that allow timely and flexible action by laboratory managers. Recent actions by both the Executive and Legislative branches have expanded measures to ensure increased competition for Federal contract awards, particularly through restrictions on accepting unsolicited proposals and discouraging sole source contracts. However, these actions may also reduce the flexibility and timeliness of contracting for basic research with universities and industry.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- *Simplifying procedures for contracting with universities.* The Department of Energy has established a working group to recommend ways to simplify contracting procedures for university research. As part of this process, DOE is converting many university awards from contracts to grants. Also, emphasis has been placed on consistent interpretation of DOE university procurement regulations and procedures by all field elements.

FUTURE DIRECTIONS

Difficulties with the Federal procurement process are not going to be overcome in a short time. Progress in this area requires continuing and relentless effort on the part of both the government and the private sector.

The peer-review system, long used by the scientific research community to ensure the relevance and worth of unsolicited research proposals, is a form of competition, albeit one operating very differently from the price competition appropriate to military hardware acquisitions. This fact needs to be more widely understood and supported within the government.

Some specific actions that need to be taken by the Federal Government are:

- Continue support of the recommendations contained in Chapter 4 of the 1983 report, *Revitalizing Federal Managment: Managers and Their Overburdened Systems*, which are aimed at a systematic reduction in the complexity of Federal procurement regulations;
- Ensure that legislation and executive orders designed to increase competition for Federal contract awards do not hinder the procurement of unique and innovative basic research, particularly through rapid response to unsolicited proposals;
- Recognize the peer review system as a form of selection appropriate to the procurement of basic scientific research, and hence satisfying the concern for competition in procurement now prevalent within government; and

- Establish the following objectives for all agencies in funding basic research:
  (1) Encourage concise proposals (usually under 15 pages) depending on the complexity and size of the project;
  (2) Safeguard the technical proposal as property of the proposer; and
  (3) Make award or reject within 6 months of proposal receipt.

SUPPORT TO MILITARY OPERATING FORCES

Recommendation 5-4: Support to the military operating forces should be an important criterion among others for measuring performance at the DOD laboratories.

PROGRESS SUMMARY

Each of the Armed Services has means for both formal and informal communication between the DOD laboratories and the operating forces. The more formal procedures ensure that operational needs are incorporated into laboratory plans through the budgetary process and are prioritized within available resources. The less formal procedures apply laboratory capabilities to meet the urgent technical needs of the operating forces.

A task force formed by the Office of the Secretary of Defense is considering new approaches to provide closer coupling of the Service laboratories with the operating forces. The task force has identified a number of Service programs wherein the laboratories provide support to the operating forces.

SELECTED HIGHLIGHTS OF AGENCY ACCOMPLISHMENTS

- The Army Materiel and Readiness Command (DARCOM) has a number of programs to identify requirements for R&D support of the operating commands. Teams of DARCOM scientists regularly conduct fact-finding missions to field units for the purpose of identifying problems in the operational use of communications equipment that require R&D solutions. DARCOM maintains 19 detachments of on-site liaison representatives at Army training centers and schools to identify problems requiring R&D support. These needs are communicated directly to the appropriate DARCOM laboratories.
- The Naval Material Command co-locates approximately 30 scientists and engineers on a rotating basis with their operational commands under the Navy Science Assistance Program. The rotational assignments provide the scientists and engineers with operational experience and improve communications with the laboratories in operational problems.
- The Air Force has a variety of procedures for identifying the R&D needs of the operating commands. Formal documents to identify logistics needs, research needs, and R&D objectives are developed through cooperation among Air Force Logistics Command, Air Force Systems Command, and the operational commands. The Strategic Air Command hosts an annual, week-long conference with laboratory participants to identify R&D

objectives and to foster informal cooperation. The Tactical Air Command has a point of contact for each development program element and is consulted for comments on relevant exploratory and advanced development programs. The Chief Scientist of the Air Force has initiated a program whereby the Chief Scientists of Air Force organizations meet semi-annually at locations of the operating forces. The goal of these meetings is to enhance interactions between the operating forces and the Air Force R&D community.

FUTURE DIRECTIONS

The DOD plans to form external advisory groups for its laboratories under the aegis of the Services' Scientific Advisory Boards. These external advisory groups will be asked to include support of operating forces among the important criteria against which they measure the performance of the DOD laboratories.

APPENDIX A

THE WHITE HOUSE

WASHINGTON

August 5, 1983

MEMORANDUM TO THE HEADS OF DEPARTMENTS AND AGENCIES

SUBJECT: Report of the White House Science Council Federal Laboratory Review Panel

The White House Science Council has recently completed a review of Federal laboratories. The report of that review notes that our Federal laboratories have great potential but that they could play a far greater role in meeting national needs if certain management and operating improvements can be made.

As we enter an era of increasing dependence on our science and technology, it is essential that we make better use of our Federal laboratories. I am directing the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) to lead an interagency effort to respond to the central thrust of the report.

A report on actions taken by the agencies in this effort should be presented to me by OSTP and OMB no later than July 1, 1984. Agency heads with responsibilities for Federal laboratories are directed to work with these offices in addressing the Science Council's recommendations.

Ronald Reagan

APPENDIX B: FCCSET FEDERAL LABORATORY COMMITTEE

DOD	USDRE	—Dr. Leo Young Director of Research & Information Department of Defense
	Army	—Mr. James E. Spates Assistant Director of Army Research and Technology Department of Defense
	Navy	—Mr. Allen W. Himes Associate Director of Navy Laboratories Headquarters Naval Material Command Department of the Navy
	AF	—Dr. Bernard Kulp Chief Scientist Headquarters Air Force Systems Command United States Air Force
USDA		Dr. William H. Tallent Deputy Administrator Northeastern Region Agricultural Research Service
DOC	NBS	—Dr. John Lyons Director National Engineering Laboratory National Bureau of Standards
	NOAA	—Dr. Joseph O. Fletcher Assistant Administrator for Oceanic & Atmospheric Research National Oceanic and Atmospheric Administration
NIH		Dr. Philip S. Chen Associate Director for Intramural Affairs National Institutes of Health
NASA		Mr. John Boyd Associate Administrator for Management National Aeronautics and Space Administration
		Mr. David Braunstein Executive Director for Special Projects National Aeronautics and Space Administration
DOT		Mr. Howard Dugoff Science and Technology Advisor to the Secretary Department of Transportation
USGS		Mr. Bruce B. Hanshaw Assistant Director for Research U.S. Geological Survey Department of the Interior

DOE	Ms. Toni Joseph Director Office of Field Operations Management Department of Energy
EPA	Dr. Donald J. Ehreth Deputy Assistant Administrator Office of Research and Development Environmental Protection Agency
OSTP	Dr. James G. Ling, Chairman Assistant Director Office of Science and Technology Policy Executive Office of the President

WORKING GROUP CHAIRMEN

Ms. Toni Joseph
Director
Office of Field Operations Management
Department of Energy

Dr. Tim P. Coffey
Director of Research
Naval Research Laboratory

Dr. Robert B. Oswald
Technical Director
U.S. Army Electronics Research and Development Command

Dr. Frank B. McDonald
Chief Scientist
National Aeronautics and Space Administration

Progress Report
ON
Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel

VOLUME II—STATUS REPORTS BY AGENCIES JULY 1984

OFFICE OF SCIENCE AND TECHNOLOGY POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20506

CONTENTS

Department of Agriculture 1
Department of Commerce (National Bureau of Standards, National Oceanic and Atmospheric Administration) 7
Department of Defense 17
Department of Energy 25
Department of Health and Human Services (National Institutes of Health) 31
Department of the Interior (U.S. Geological Survey, Bureau of Mines) 37
Department of Transportation 44
Environmental Protection Agency 50
National Aeronautics and Space Administration 55
Acronym Glossary 60

DEPARTMENT OF AGRICULTURE

MISSION

Recommendation 1-1: Mission Review

In February 1983, the Agricultural Research Service (ARS) announced new directions for agricultural research in the 1980s with emphasis on research on critical national needs up to 1990 and projected over the next 20 to 50 years. Some 500 ARS scientists and members of the National Program Staff (NPS) were asked to devise a strategy that would provide, through research, the means by which U.S. agriculture could meet these needs. In response, they developed a document, the ARS Program Plan. The plan records the best thinking of these scientists and NPS members on how ARS can meet the Department of Agriculture's (USDA's) short- and long-term needs most effectively and efficiently.

ARS is redirecting its scientific talent and resources in line with Secretary of Agriculture Block's policy to focus research on national goals. The ARS is projecting that $75 million of its current budget be redirected over 6 years, from 1984 to 1990. A revised program of Forest Service (FS) research under the provisions of the Renewable Resources Planning Act is now in preparation and will be submitted in December 1984.

Recommendation 1-2: Size of Laboratory

The Program Plan includes programs for meeting future, as well as present, needs of U.S. agriculture. On the basis of recommendations by the scientists and the NPS, and guided by USDA policies, a 6-Year Implementation Plan was prepared. In it are identified the programs of highest priority that ARS will support first. The projected resource allocations for those high-priority research programs are being developed. This information will guide decision making by management at all levels in ARS. Programs will be evaluated systematically to identify areas of significant progress, major constraints to further progress, emerging research problems and opportunities, and research that can be discontinued.

The ARS continues to seek ways to improve the efficient use of its facilities and to give increasing emphasis to the optimum use of facilities as redirections prescribed in the 6-Year Implementation Plan are carried out.

The total Forest Service research program is reviewed annually, and assignments to the eight Regional Forest and Range Experiment Stations and the Forest Products Laboratory (Madison, Wisconsin) are adjusted in accordance with long-range research plans and Congressional action.

FUNDING

Recommendation 3-1: Multiyear Funding

From 1975 through 1984, the Agricultural Research Service received steady increases from $218 million to $453 million. In constant 1984

dollars, the increase was from $425 to $466 million. During that time, yearly effort was approximately constant at 2,800 scientist-years while total employment decreased from 9,350 to 8,546. Thus, stable funding appears to have been provided. However, late funding of pay raises caused a significant impact on planning. The USDA's experimental research organizations are primarily in-house with salary costs typically ranging from 65% to 85% of total funds available. A 5% pay raise that must be funded from nonsalary funds reduces those funds from 9% to 28%. Current timing of pay raise decisions requires fundholders to "set aside" those amounts, often until one-half to three-quarters of the fiscal year is over, before they can make final funding decisions. Late appropriations cause similar uncertainties which impact final decisions.

The primary Federal research laboratories in the USDA are in the Agricultural Research Service and the Forest Service. Both receive appropriations directly with no "overhead" taken at the Department level. Both agencies have planning systems that enable proper, predictable multiyear planning except for the impact of late appropriations and unfunded or partially funded pay raises. Neither agency has the flexibility to "absorb" unfunded pay raises except from all other funds that directly affect planned experiments. Thus, the USDA supports the recommendation. If a 2-year budget is not appropriated, full funding of pay raises and a 2-year budget or carry-over authority of unobligated funds would greatly contribute to the proper planning of the Department's research efforts. Full funding of pay raises is by far the most critical aspect, followed by a 2-year budget or carry-over authority.

The Office of Management and Budget (OMB) must request and Congress must fund pay raises; Congress must grant carry-over authority and appropriate funds accordingly, or Congress must appropriate a 2-year budget. If government-wide authority is not obtained, the appropriation committees of the Congress will be requested to fully fund all pay raises for personnel in the Department.

Recommendation 3-2: Discretionary Funds

The USDA laboratories do not have any formal discretionary funds. USDA Federal laboratory directors, however, have authority to decide the subject matter and methodology of research activities and, in exercising this authority, have some freedom to undertake exploratory research. As a result, the decision making authority of USDA managers allows for a degree of discretionary use of funds. The only review of these discretionary decisions occurs in general program reviews or in managers' performance ratings.

The Department supports the recommendation but believes it can accomplish the intent without establishing a formal discretionary fund. A policy statement will be issued by agency heads on the equivalence to formal discretionary funding authority of 1) determining research goals and approaches, and 2) freedom to do exploratory research. The statement will also establish guidelines on the amount of permitted exploratory

research and a review system so that the amount of equivalent discretionary funding authority can be raised or lowered depending on the effectiveness of its use.

USDA will charge appropriate staff or a special committee in the Forest Service and Agricultural Research Service to develop the policy statements. After appropriate review, the Chief of the Forest Service and Administrator of the Agricultural Research Service will issue the policy statements.

Selected Department officials have been briefed on the concept and have concurred in the general approach.

Recommendation 3-3: Carry-Over Funding

P.L. 95307, "The Forest and Rangeland Renewable Resources Research Act of 1978," provides basic guidance to Forest Service research. Section 7 of this Act states, "There are hereby authorized to be appropriated annually such sums as may be needed to implement this Act. Funds appropriated under this Act shall remain available until expended." However, this authority has never been extended by Congress to the Forest Service during the annual appropriation process. Therefore, to date, Forest Service research funds have been appropriated only as annual funds. The Agricultural Research Service has no authority to carry over unobligated funds except for construction and rare special programs of a temporary nature.

The USDA supports the recommendation. If the predictable funding recommendation is not implemented (2-year budget), the Department will request that a minimum of a 120-day grace period be permitted to carry over expiring appropriations.

If the predictable funding recommendation is implemented, no action is required. If not, the Department must request carry-over authority through OMB, and the Congressional appropriation committees must grant carry-over authority.

MANAGEMENT

Recommendation 4-1: Oversight Function

ARS reviews each research project at least once every 3 years. Review panels include research leaders from the laboratories under review and scientists from other government agencies, the academic community, and industry. The review and evaluation of research programs at many levels in ARS serve to identify areas of significant progress, major constraints to further progress, emerging research problems and opportunities, and research that can be discontinued. That information is used in setting priorities, planning and implementing redirection, developing budgets, and revising the 6-Year Implementation Plan and the operational plans. The National Program Staff is responsible for reviewing national programs and for evaluating their progress and consistency with the 6-Year Plan.

A continuing schedule of technical review of Forest Service research units monitors performance and productivity. These reviews include peer specialists from universities, private industry, and state forest agencies.

Recommendation 4-2: Greater Reliance on Peer Review

A system is in place that provides for peer review of each research project before implementation.

In the application of the Research Grade-Evaluation Guide, grade levels for scientific positions are determined by committees (often referred to as peer panels) rather than by a single classification specialist—the usual practice in the Federal Government. Scientists prepare written material describing their research assignments and their accomplishments, and an appropriate panel periodically reviews the position. Panels consist of a committee chairperson (usually a research manager), an executive secretary (a classification specialist), and five scientists.

The peer review and evaluation systems will be reviewed periodically and revised when necessary.

Recommendation 4-3: Finite Term for Laboratory Director

Funds are appropriated by Congress for specific research programs. ARS headquarters allocates those funds to Area Directors (AD's). Each AD is responsible for controlling allocated funds and for assuring that the research program is carried out. Performance of ARS managers is evaluated annually.

A major reorganization of ARS has just been put in place that reduces the number of AD's to 11, (one of whom is director of the Beltsville Agricultural Research Center), eliminates one layer of administrative management, and provides for more direct interaction between research managers in the field and the National Program Staff at Headquarters. The AD's have primary responsibility for the quality of their research programs and work with the NPS in assuring program relevance and conformity with the ARS Program Plan and 6-Year Implementation Plan. The AD's are formally evaluated annually for their effectiveness in fulfilling these responsibilities, and, as members of the Senior Executive Service (SES), they can be reassigned as appropriate to improve program leadership and management.

Forest Service funds are appropriated annually by Congress for specific research subjects as enumerated in the Renewable Resources Research Act of 1978. These funds are allocated to the eight regional experiment stations and the Forest Products Laboratory (FPL) pursuant to their assigned missions and respective roles in the total FS research program. Like AD's, FS experiment station and FPL directors are in the SES.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

In 1983, USDA issued a Departmental Regulation on Research and Education Policy which states that it is the policy of the Department to:

". . . enhance and preserve partnership relations among research and education performers within the total State, Federal and private system."

USDA policy and practice have always been to promote access to research laboratories. This has been successful. For example, in 1981-1982, approximately 2,000 persons visited nine Agricultural Research Service laboratories seeking information and scientific advice. Joint use of equipment and facilities by university and USDA personnel is also practiced at numerous locations—about 50 percent of ARS scientists are located at or adjacent to university facilities. ARS scientists devoted approximately 3.6 percent of their time in 1983 to make more than 60,000 contracts with users of ARS research results. These users included action and regulatory agencies, extension services, farmers and ranchers, agricultural industry, state and local governments, and consumer groups.

Forest Service research results are communicated by means of technical publications, articles in scientific and user journals, workshops, and responses by scientists to individual requests for technical information. Since much of the research is used in the management of the 191 million acres of National Forests, particular attention is given to internal communication of research results within the Forest Service. This takes many forms, including workshops and preparation of concise management guides based on research findings. The State and Private Forestry Branch of the FS has the responsibility to supplement the technology transfer of applied research to the state forest land management agencies and to private forest landowners. This is done through technical meetings, special workshops, and joint efforts with state forestry agencies and others. In total, FS technology transfer utilizes a variety of avenues to communicate research results to the scientific community, within the agency itself, and to other research users. Also, forestry research cooperation with university and private sectors is fostered through joint research planning between the FS, the Cooperative State Research Service, and the Association of State College and University Forestry Research Organizations.

Published technology transfer plans are in place to broaden the clientele accessing USDA laboratories. Included will be targeted groups, such as Small Business Development Centers.

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

Many USDA researchers maintain close rapport with representatives of industrial firms relevant to their research. This interaction is encouraged and taken into account as part of the scientists' evaluations. At other levels, industry representatives serve in many formal and informal

advisory roles to departmental, agency, and program managers. Industry groups also contract with USDA agencies to conduct specialized research projects within established guidelines. In 1983, ARS scientists made an estimated 15,000 contacts with industry personnel to plan and conduct research and to transfer technology.

Funds allocated by USDA for competitive research grants total $17 million in fiscal year 1984. All universities and industrial R&D organizations are eligible to compete for these grants. Increased utilization of sabbatical assignments and non-competitive temporary Federal appointments will be explored for increasing exchange of personnel between USDA and industry.

DEPARTMENT OF COMMERCE:
NATIONAL BUREAU OF STANDARDS (NBS)
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

MISSION

Recommendation 1-1: Mission Review

NBS:

The Department of Commerce (DOC) held strategic Planning Reviews for the National Bureau of Standards (NBS) in September 1982. The NBS mission was thoroughly reviewed and the programs were grouped in three categories: providing a basis for measurements throughout the United States; providing technical assistance to the Federal Government as mandated by Organic Act or legislative assignments; and assisting in solving technological problems that are measurement and test-method intensive.

NBS receives authorization each year by separate Act of Congress. Its mission is therefore updated annually. In addition, NBS testified at Congressional hearings on the NBS Organic Act held in June 1981. The hearings were held "to examine how well the Bureau's present charter serves present needs and covers the activities actually performed by the Bureau; and to determine how the Bureau can and should serve these and other Federal and national needs for research and development by government, industry, and the universities in future years." Following the hearings, DOC/NBS prepared a revised version of the Organic Act for consideration by Congress. The draft clarifies and modernizes the basic functions and activities of NBS.

NOAA:

In the fall of 1982, the Administrator of the National Oceanic and Atmospheric Administration (NOAA) initiated a long-term planning process, the first step of which included consideration of roles appropriate to Federal laboratories and the Federal Government. National needs were listed, and from these candidates future programs and activities were recommended. In response to the report of the White House Science Council's Federal Laboratory Review Panel, the Administrator had the mission statements of all NOAA laboratories and Fisheries Centers revised and updated. The Administrator also conducts, over a cycle of about 18 months, reviews of program areas (e.g., marine quality, marine resources, etc.) that involve more than one laboratory and organization element within NOAA. These reviews are part of the basis used for reassigning responsibilities and priorities within the agency.

Recommendation 1-2: Size of Laboratory

NBS:

Compared with similar laboratories in other industrialized countries, NBS is substantially smaller relative to the size of Gross National Product. In

addition to those activities defined under the Organic Act, NBS has been assigned 22 Congressionally mandated programs. NBS is rebuilding the basic competence that has been eroded due to combined budgetary and personnel constraints and added Congressionally mandated programs. A competence building program initiated in fiscal year 1979 and continued through fiscal year 1983 is currently funded at $7.0 million/year.

The institutional planning process of the Department of Commerce during the budget formulation and review process and the strategic planning objective exercises—coupled with external review processes by peer groups, Statutory Visiting Committee and Evaluation Panels—ensure the quality, importance, and priority of programs, quality of staff, equipment needs, finances, and appropriateness of the program to NBS mission. In addition, the Director and heads of the major operating units reprogram resources to answer the identified priority needs of science and technology. This reprogramming has resulted in a 40% turnover in NBS projects during the last 5 fiscal years.

NOAA:

NOAA has produced a draft long-range plan for research which is to be updated annually. The planning process begins with an analysis of national needs, of the appropriate Federal role in meeting them, and of NOAA's responsibilities. The Administrator makes program direction decisions on the basis of options in the plan, and these are promulgated to the laboratories with relevant missions. The funding and personnel allotments are adjusted accordingly after Congressional appropriations.

As a result of this DOC/NOAA process, the size of the laboratories is adjusted automatically each fiscal year to be compatible with the funding approved by the President and appropriated by Congress for their respective program areas.

FUNDING

Recommendation 3-1: Multiyear Funding

NBS:

NBS receives separate designated appropriations from Congress. NBS currently has appropriations for a 1-year period with unlimited carryover authority.

NBS supports R&D funding on a 2-year basis if that funding is predictable. The appropriation would have to allow for increases for pay raises, cost of living allowances, and supplementals for unforeseen circumstances of a significant nature.

All Congressional authorizing and appropriations committees would have to approve the changes. Departmental and Office of Management and Budget (OMB) policies would have to be brought into line with this method of funding.

NOAA:

Funds are appropriated on an annual basis, with no separate appropriation for research. Base budget is very stable at the laboratory level.

Instability due to annual appropriation is not a problem. No recommendation is made for multiyear funding or for a separate research appropriation.

Recommendation 3-2: Discretionary Funds

NBS:

NBS currently has "competence funding" for use in the long-term research mission. This can be considered discretionary funding, and constitutes 7% of total funds. These funds are used to develop research competence in areas that management views as potentially important in the long-term mission of NBS. The use of these funds is reviewed by the National Academy of Sciences (NAS). NBS has full liberty to execute its program as it deems appropriate, whether in-house or contracted through academia or industry.

No change in funding is necessary to meet the recommendation.

NOAA:

NOAA laboratories currently have no discretionary funds. If urgent needs for new programs on the frontiers of science arise, the agency will reprogram to make funds available. Provisions for discretionary funds would be helpful in meeting this recommendation.

NOAA will request discretionary funds as part of future budget initiatives.

Recommendation 3-3: Carry-over Funding

NBS:

NBS currently has carry-over funding authority.

NBS concurs in need for carry-over authority. Many programs that are delayed need carry-over authority to properly fund the completion of the mission.

NOAA:

NOAA has no-year funds, with no restriction on obligation rates. No change in funding is necessary to meet the recommendation.

MANAGEMENT

Recommendation 4-1: Oversight Function

NBS:

NBS reports its program annually to a two-tiered external oversight function: the Statutory Visiting Committee appointed by and reporting to the Secretary of Commerce and, for each technical program, a Board of Assessments administered by the National Academy of Sciences. During 1981, Secretary Baldridge requested a critical review of all advisory committees within the Department to determine which ones could be terminated. The review covered a total of 89 committees and considered funds expended and products produced. None of the committees was terminated. However, several cost reduction measures were put into place. The formation of another advisory committee appears inconsistent with the

Secretary's actions. Moreover, a proposed Project Evaluation Committee (as recommended in the Grace Commission Report) is redundant with the existing Visiting Committee/Evaluation Panel structure and would be an unnecessary duplication of effort.

NOAA:

NOAA conducts regular reviews both of laboratories and of program areas. Members of industry, academia, and user groups are represented on the review committees. These members are invited on a case-by-case basis. In response to the report of the White House Science Council's Federal Laboratory Review Panel, the process of including outside reviewers and requesting their written reviews has been documented and formalized. The National Marine Fisheries Service (NMFS) is also subject to external oversight by two formally established advisory committees which scrutinize the quality and relevance of the laboratories' activities. These are the National Committee on Oceans and Atmosphere (NACOA), which has oversight for all of NOAA, and the Marine Fisheries Advisory Committee (MFAC), which has oversight for the NMFS. The question of external reviews was discussed at the NMFS Research Council in May 1984, and it was decided that the present system is adequate and that additional processes for accomplishing external oversight are not needed. Plans are to establish a group of advisors to review both the laboratory programs and the research programs across NOAA line organizations.

Recommendation 4-2: Greater Reliance on Peer Review

NBS:

Continuous peer review of NBS activities is assured by a variety of methods.

The Director and the major operating units use the annual reports of the Statutory Visiting Committee and NAS-administered Board of Assessments of NBS programs to assess fundamental long-range research plans and activities. This research must satisfy one or more of the following criteria: furthers the development of standards, data and/or measuring techniques; serves a national need such as defense; answers a technological need.

Industrial, academic, and standards groups advise NBS on technological, measurement, and data needs.

NBS uses advice from ad-hoc industrial, government, and academic groups in assessing its future role in specific long-range research initiatives.

An internal peer review process is used to target new areas of fundamental research for competence building. The advice of outside scientists is also sought as to the merits of these proposed long-range fundamental research programs.

The planning of large facilities (e.g., cold neutron facility and cw-accelerator) to meet the needs of industry, academia, and other government agencies is accomplished in coordination with potential user groups

and other interested parties (e.g., the National Science Foundation, the Office of Science and Technology Policy,and the Department of Energy).

NOAA:

Peer review has always been accomplished to a significant degree, and by the usual processes, i.e., of publication in peer-reviewed scientific journals, attendance and presentation at professional meetings, interaction with other scientists in committees and working groups, and exchanges of personnel. However, feedback has not been assured in all cases. Partly as a result of the White House Science Council's report, the NOAA Administrator has had his personal staff investigate the peer review process in NOAA. The outside review process will be strengthened by giving the outside reviewers of both laboratories and program areas a written charge and obtaining written feedback. In addition, a small "board of visitors" will assist the Assistant Administrator for Research to provide advice and broad overview.

Recommendation 4-3: Finite Term for Laboratory Director

NBS:

DOC has instituted a management by objectives system by which an agreed upon set of strategic planning objectives (SPO's) with their specific measurable milestones constitutes the individual performance plan of the NBS Director. As a Presidential appointee, the Director's tenure will continue to be at the pleasure of the President, and his performance will be evaluated on a regular basis by the Visiting Committee and by the Secretary of Commerce. The Director will be held accountable in fiscal year 1984 by the Secretary of Commerce for the accomplishment of a set of 10 SPO's, each of which has a number of milestones with measurable outputs.

NOAA:

Laboratory and Fisheries Center directors are members of the Federal Senior Executive Service (SES), serving under contracts reviewed twice a year. These contracts require adherence to predetermined standards in laboratory performance. The SES contract and review process thus provides the opportunity to terminate contracts if laboratory performance is not acceptable. Although not related to performance, the directors of seven laboratories and centers have changed in recent years, illustrating the flexibility of the personnel system.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

NBS:

As a matter of mission, and in compliance with legislation of 1901 responsive to Alexander Graham Bell's proposal, the NBS makes its laboratory facilities readily accessible. About 750 guests are currently acquiring "hands-on" experience in NBS facilities under various formal programs. NBS brochures describe about 100 special technical facilities

and several hundred research topics to attract researchers. NBS facilities are generally designed to provide space for guest investigators. Examples follow.

The Experimental Nuclear Reactor has 25 ports providing 125,000 instrument-hours per year to more than 50 guest groups for research involving neutron scattering, measurement standards, dosimetry, trace analysis, isotope production, and radiation.

The Synchrotron Ultraviolet Radiation Facility (SURF) provides 280 MeV highly collimated, nearly polarized radiation of calculable intensity in 6 beams.

The Linear Accelerator (LINAC) accelerates electrons to energies between 1 and 10 MeV in a beam directed to either of two heavily shielded underground target rooms or to an above-ground target room where secondary neutron beams are produced for time-of-flight meausurements across distances up to 200 meters.

NBS has a variety of arrangements for joint research with universities. At the Joint Institute for Laboratory Astrophysics (JILA) in Boulder, for example, 13 NBS staff members join with 11 faculty members of the University of Colorado to conduct research involving precision measurement in physics, chemistry, and astro-geophysics. One hundred and forty three additional invited scientists and students join in the research on a revolving basis. NBS facilities are continually being upgraded and new arrangements made for joint research with institutions of learning.

NOAA:

NOAA provides access to its Federal laboratories through a variety of mechanisms: cooperative institutes with state and local universities, reimbursable programs, Intergovernmental Personnel Act (IPA), postdoctoral program, visiting scientists, and direct access to special facilities. Cooperative institutes between NOAA and universities have been established in Hawaii (JIMAR—Joint Institute for Marine and Atmospheric Research), Washington (JISAO-Joint Institute for Study of the Atmosphere and Ocean), Colorado (CIRES—Cooperative Institute for Research in Environmental Sciences and CIRA—Cooperative Institute for Research in the Atmosphere), Oklahoma (CIMMS—Cooperative Institute for Mesoscale Meteorological Services), and Florida (CIMAS—Cooperative Institute for Marine and Atmospheric Studies); and a cooperative program has been established in New Jersey. On the average, NOAA has around a dozen IPA's that range from 1-year to 4-year assignments, but the number varies from year to year. Guest worker arrangements are made between the individuals and the NOAA laboratories, but on the average about 50 guest workers per year work in the laboratories. Arrangements for direct access to laboratory facilities are usually made directly by the laboratory and the user; these are not long-term arrangements. Examples of direct access to special laboratory facilities include the Boulder Atmospheric Observatory studies, the Coastal Ocean Dynamics Applications Radar (CODAR) Program, and the Hurricane Program.

Direct access to laboratory facilities is demonstrated by a wide variety of examples. NOAA aircraft and ships are available for researchers and

investigators from external agencies and groups. Flights and cruises are often composed of NOAA researchers augmented by university, other agency, and private sector scientists. These field programs are planned through proposal submissions from various researchers, one year in advance. Once preliminary agreement has been achieved and a set of field programs has been scheduled, additional pieces of research are added to each of the field programs to fully utilize the capacity of the ships or aircrafts. For example, in fiscal year 1983 the Arctic Gas and Aerosol Program grew into a research program composed of scientists from 3 Federal agencies, 10 universities, 2 Federally sponsored private laboratories, Canada, and Norway. The program consisted of research on air pollution sources and content of the "arctic haze," on the development of polar lows over the North Atlantic, on the stratospheric-tropospheric exchange of particles from El Chichon, and on the extent and movement of ice in the polar region. In addition to these moving platforms, NOAA has fixed laboratory facilities that are accessible to universities, industry, and users of research—the Boulder Atmospheric Observatory (BAO), the National Severe Storms Laboratory's radar and lightning net, the Program for Regional Observing and Forecasting Services, the Space Environment Service Center, and the NOAA Undersea Research Program (NURP) are examples. Each of these facilities is available for cooperative programs, can provide direct services, and is accessible to outside users.

Recommendation 5-2: R&D Interactions Between Federal Laboratories and Industry

---

Department of Commerce (Productivity, Technology, and Innovation)

As the agency with lead responsibilities for Federal patent policy and the Stevenson-Wydler Technology Innovation Act, the Department of Commerce has been working to develop several government-wide policies that are consistent with the Packard Report recommendations.

The Department helped draft legislation allowing nearly all government R&D contractors to own inventions that result from Federal funding. This would automatically transfer ownership of technology developed by contract operators of government-owned laboratories to the contractors. Experience with universities shows that contractor ownership is a particularly effective form of technology transfer and leads to closer interaction with industry.

In addition, the Department has proposed legislation that would allow agencies to protect their procurement interests in Federally developed technology through use of a "Statutory Invention Disclosure." With this technique available for defensive use, agencies would only file for conventional patents on inventions—mostly from laboratories—that have commercial potential. This would reduce the government patent portfolio to the relatively few inventions most likely to be useful to industry. Again, the university experience shows that concentrating on valuable inventions leads to many forms of industry cooperation.

The Department also is developing a plan for managing Federal technology, particularly that developed in the laboratories. Key elements of the plan include incentives for closer cooperation with industry and provisions for laboratory inventors to assist in commercialization efforts.

Further, the Department has fostered use of Research and Development Limited Partnerships by the private sector to fund major technological advances. It is hoped that the facilities and staff of Federal laboratories may be involved in significant partnership developments.

The Department, through its Center for Utilization of Federal Technology, is providing several important aids to help industry identify useful Federal laboratory expertise.

NBS:

As the U.S. Central Reference Laboratory, NBS collaborates with U.S. industry in developing the measurement services needed to create, make, and sell competitive products and services. The NBS Statutory Visiting Committee, composed of five leaders of U.S. science and technology, is assisted by more than 200 leading industrial and university scientists and engineers in overseeing NBS plans, programs, and services.

NBS is currently improving its traditionally strong links to industry. For example, NBS joined with the Industrial Research Institute (IRI, whose members carry out 85% of U.S. industrial R&D) and the Commercial Development Association (whose members commercialize most of the U.S. R&D) in a survey to determine the extent of their interest in Federal R&D, how they acquire knowledge of such R&D, and how they would like to be kept informed of it—particularly the R&D carried out at NBS.

NBS recently assessed industrial interest in NBS research and development and found 219 relevant projects. These projects were test-marketed among industrial firms; NBS top executives also increased their presentations to various industrial groups. NBS developed a "How-To Primer" for Federal laboratory technology transfer and a "Federal Laboratory Directory" under the auspices of the Federal Laboratory Consortium. NBS arranged and participated in workshops in which Federal laboratories and industrial firms presented discussions of emerging technological developments. NBS has placed emphasis on the development of measurement services for high-performance semiconductor electronics, flexible automatic manufacturing, chemical engineering, materials processing, and biotechnology. Quality-control training seminars are being held throughout the United States in important industrial-process areas sensitive to measurements. Examples of external interactions not previously mentioned are:

NBS provides technical advice to 1,497 national and international standards committees and answers 5,000 inquiries about national and international product standards and practices each year.

40,000 certified samples of materials are supplied to 10,000 clients yearly.

7,000 instruments are calibrated each year.

2,000 energy-related inventions are evaluated yearly and inventions expositions are hosted throughout the Nation.

280 construction-material test laboratories are evaluated each year.

NBS has formal cooperative R&D programs with 16 industrial firms and 24 trade associations.

NBS has received approval to make its facilities available to private sector users on a controlled basis for conduct of research of a proprietary nature.

NOAA:

NOAA provides access to its Federal laboratories by industry through several mechanisms: the Office of Research and Technology Application (ORTA), guest workers (described in recommendation 5-1), laboratory outreach programs, and cooperative programs.

The ORTA, established in compliance with section 11 of the Stevenson-Wydler Technology Innovation Act of 1980, has appointed contacts in each of NOAA's laboratories. The ORTA serves as a focal point for the collection and distribution of information products about technologies developed in NOAA laboratories. In cooperation with laboratory personnel, Technology Briefs are written and distributed through a growing network of technology transfer organizations. These include the DOC Center for the Utilization of Federal Technology, the Federal Laboratory Consortium, the Sea Grant Marine Advisory Service, NOAA extension services, the non-Federal Technology Transfer Society, and state organizations such as the Ohio Technology Transfer Organization (OTTO).

Laboratory outreach programs include individual laboratory efforts to move their technology or products to the marketplace. Specific examples are the Coastal Ocean Dynamics Applications Radar (CODAR), the Doppler radar and lightning data, the NOAA Undersea Research Program (NURP), the Hurricane Program, and the data from the Geophysical Monitoring for Climatic Change (GMCC) Program. CODAR is a high-frequency radar technique developed in NOAA's Wave Propagation Laboratory to measure wave and current information from coastal sites. This technology was made available to industry, and at least one company was formed to manufacture and use this system.

The fishing industry is directly involved with the NMFS specialized facilities for new product development, product storage and handling, product quality and safety, and fishing gear development. Through these specialized research facilities the NMFS has cooperative agreements, exchange of personnel, and exchange and sharing of equipment with industry.

NOAA has attempted to expand the interaction between the laboratories and industry where appropriate. New technology for remote sensing in the atmosphere and the oceans is being developed in the research laboratories. Passive and active sensors to measure wind, temperature, humidity, and total water content are being developed. Industry, through joint programs, will be called on to develop operational prototypes for these devices. New techniques for gathering and displaying various data sets and combinations of data sets are being developed. Industry, again through joint programs, will be called upon to move these concepts into prototype systems for evaluation by NOAA service organizations.

The Geophysical Monitoring for Climatic Change Program maintains a long-term record of various atmospheric constituents that are considered a measure of the "health" of our atmosphere (e.g., carbon dioxide and ozone). These data are made available, on a regular basis, to industry and other users.

Recommendation 5-3: Simplification of Federal Procurement Procedures

The Department of Commerce has been working to extend the right of invention ownership to all classes of R&D contractors. Experience with universities shows that contractor ownership simplifies R&D procurement procedures and is a particularly effective form of technology transfer. The Department drafted and coordinated the President's February 18, 1983, Memorandum that established contractor ownership as the Administration's policy. The Department assisted in re-writing the patent section of the new government-wide Federal Acquisition Regulation (FAR) to make it conform with statutes and the Presidential Memorandum. The Department has also assisted in drafting new patent-ownership legislation.

DEPARTMENT OF DEFENSE

MISSION

Recommendation 1-1: Mission Review

The missions of Department of Defense (DOD) laboratories clearly define their role as that of performing basic and applied research for the development of military technology and equipment. These are recognized by the Packard Report as appropriate roles for Federal laboratories and are two of the major functions listed in a DOD study of required in-house capabilities for research, development, test, and evaluation (RDT&E).

Following a recent review of its laboratory organization study, the Air Force has reorganized its laboratories, placing them in product divisions to promote closer ties between the research community and the research users. The Navy completed a study in 1983 of the mission statements of the 13 laboratories that account for over 95% of the Navy's laboratory work force. The Army Materiel Development and Readiness Command (DARCOM) initiated a comprehensive review of its 20 laboratories, including their roles and missions. These laboratories account for approximately 75% of the funds that go to Army laboratories. The review is expected to be completed in 1 year.

Recommendation 1-2: Size of Laboratory

DOD laboratories are sized to accomplish their mission. Whereas doing good science may justify an increase in size of a university science department, DOD cannot justify changing the size of a laboratory based on the quality of its work alone. The quality of work is extremely important and is assessed by management and sponsors at various levels. Improving quality is always a goal.

DOD will continue to review the roles and missions of its laboratories using the results of its "Required In-House Capabilities" study as a guideline. Laboratories will continue to be sized based on mission requirements. Quality of work will be continuously reviewed by management, sponsors, and the external advisory groups being set up in response to recommendation 4-1.

FUNDING

Recommendation 3-1: Multiyear Funding

ARMY:

RDT&E funds are appropriated on an annual basis. Civilian pay raises are paid out of the RDT&E budget; there are no separate appropriations to cover such raises.

There is no evidence that a 2-year budget would provide stability to technology base funding. Supplemental RDT&E funds are needed to cover civilian pay raises to minimize turbulence in R&D mission areas.

The Office of the Secretary of Defense (OSD) must submit a pay supplemental that includes RDT&E appropriations to cover civilian pay raises for all Services. The Office of Management and Budget (OMB) should approve and forward these requests for Congressional action.

NAVY:

Funds are appropriated on an annual basis.

The Navy supports across the board R&D funding on a multiyear basis.

OSD/OMB/Congress must approve and implement multiyear appropriations.

AIR FORCE:

Funds are appropriated on an annual basis The Air Force currently funds civilian pay raises out of non-technical resources.

The Air Force does not consider instability to be a problem. It can support basic and applied research multiyear funding but prefers to deal on a year-to-year basis for big projects. The Air Force would be pleased if Congress appropriated funds to cover the pay raise.

Congressional action is required to effect a pay-raise appropriation.

Recommendation 3-2: Discretionary Funds

ARMY:

Discretionary funds constitute 10% of the Army's basic research programs; no such funds are available in the applied research program. Laboratory directors report annually, reviewing program progress, to support future funding. Laboratory directors have unrestricted use of these funds. However, in-house research is strongly encouraged. As a result, approximately 20% of these funds are used for contractual effort; 80% are used for in-house research.

No change in funding is necessary to meet the recommendation.

NAVY:

Discretionary funds have been available to Navy research activities under basic research since the mid-1950s. Applied research discretionary funding was started in the mid 1960s. The laboratory directors are given wide latitude in the use of discretionary funds to enable them to perform innovative, promising work without the procedure of formal and prior approval. The laboratory director has the authority to contract out to universities and/or industries research work that supports in-house efforts. The Navy's discretionary programs are evaluated after the fact, based primarily on biennial site reviews by the Chief of Naval Research review teams. These reviews are interspersed in alternate years by laboratory presentations to other laboratory directors and a selected panel of high level Navy research officials. A recent unpublished study of the Chief of Naval Material research centers' discretionary program (fiscal year 1966-fiscal year 1981) has revealed a sharp decline in discretionary funding while

the number of scientists and engineers engaged in discretionary programs has been cut in half since fiscal year 1967 due to decreased funding.

The Navy supports the recommendation as written. This recommendation is supported to a degree by the DOD budget guidance regarding funding of discretionary programs, which states: "However, no more than 5% of a given laboratory's funding will be in the form of In-house Laboratory Independent Research and Independent Exploratory Development (discretionary) funds." The Navy laboratories' funding for discretionary programs amounts to less than 2% of total laboratory funds. An increase to 5% would be in line with laboratory directors' needs based on a recent Navy study. It has been proposed that the "annual funding" portion of the recommendation be interpreted to mean "technology base" funding. This interpretation is considered too restrictive and it is not in line with existing DOD budget guidance for the discretionary programs.

Due to the large decrease in funding for the Navy's discretionary programs, the Director of Navy Laboratories is seeking to stem the continued down-slide by trying to establish some policies that would provide growth to the discretionary programs with particular emphasis on sizable growth in applied research in the near future. The study of the Navy laboratories' discretionary programs, cited earlier, stated that laboratory funding needs for the discretionary program amount to over 4% of the laboratories' total annual funding. Currently the Navy laboratories' discretionary program amounts to less than 2% of their total funds. Therefore, the laboratory directors feel that a significant increase in discretionary program funding is required to maintain the Navy's efforts at a reasonable level to attract highly qualified scientists and engineers and to help develop and retain a sound core of in-house expertise.

The Office of Naval Research has agreed to maintain discretionary funds as a constant percentage of basic research funds (about 7%). The Office of Naval Technology has agreed to increase the percentage of discretionary funds as a part of applied research funds (from 2% to about 5%).

AIR FORCE:

The Air Force currently maintains discretionary funds in basic research equal to 7% of the basic research budget. The Office of the Assistant Secretary of the Air Force reviews the results of basic research once a year. Laboratory directors may use basic research discretionary funds both for work done in-house and through contracts with academia and industry.

The Air Force will maintain basic research discretionary funds and initiate applied research discretionary funds.

The Air Force Systems Command will initiate and administer discretionary funds for applied research.

Applied research discretionary funds equal to 0.5% of each laboratory's applied research budget will be available for use by the laboratory director in fiscal year 1985. The percentage will increase gradually to 4% of total applied research in fiscal year 1989 and thereafter. These funds will be used for unplanned opportunities and will not be available to cover

cost growths or other problems in the planned portion of the laboratory programs. Performance of discretionary funded programs will be a factor in distribution of future discretionary funds among Air Force laboratories.

Recommendation 3-3: Carry-over Funding

ARMY:

The Department of the Army has 2-year R&D obligation authority. However, because of incremental funding guidance, the Army attempts to obligate in excess of 96% of its funds in the first year and 100% in 15 months.

There are no major problems with execution of technology base programs within the time limits as related to ongoing contracts. However, with new procurement regulations, obligation goals under Continuing Resolution Authority may not be realistic. No change in funding, however, is necessary to meet the recommendation.

NAVY:

In accordance with regulations in NAVCOMPT manual, Volume 7 paragraph 074403, RDT&E,N funds are incrementally funded to government installations (Federal laboratories) during the first year of this 2-year appropriation. The planned increment may extend up to 3 months into the following fiscal year per the authority of the Assistant Secretary of the Navy (Research, Engineering and Systems). New obligations are limited to the period of October 1 of the first fiscal year to December 31 of the second fiscal year.

If an extension of Obligational Authority is needed beyond December 31, an extension may be requested of the Assistant Secretary of the Navy (Research, Engineering and Systems). The RDT&E,N annual obligation rate established by OSD is 94%. In the first year of the appropriation, technology base funds normally reach this goal within the Navy. Therefore, due to the aforementioned, few problems are encountered concerning carrying remaining technology base funds forward into the next fiscal year.

No change in funding is necessary to meet the recommendation.

AIR FORCE:

Air Force RDT&E funds are 2-year appropriations. To assure timely appropriation and distribution of funds, the general objective is to obligate and expend current fiscal year funds for work to be done in the current year. Specific OSD goals are 94% for obligation and 61% for expenditure by the end of the first year. Contracts are incrementally funded, i.e., work done in second and subsequent years is paid for with funds appropriated in those years. However, laboratory directors have authority to obligate and expend funds in the second year of an appropriation for programs that have been delayed. After December 31 , Headquarters Air Force Systems Command determines the status of laboratory funds that have not been committed to procurement, and may reallocate funds between laboratories to assure that the funds are appropriately obligated by the end of the second year.

MANAGEMENT

Recommendation 4-1: Oversight Function

Implementation of this recommendation is in process at DOD. The Services were requested to form external advisory groups for their laboratories under the aegis of their Scientific Advisory Boards and to provide plans for how these groups would operate to perform the oversight functions. For the most part, the advisory groups will be constituted under the Naval Research Advisory Committee (NRAC), the Army Science Board (ASB) and the Air Force Scientific Advisory Board (SAB). The Army Medical R&D Command already has a separate advisory board for its laboratories. The Office of the Secretary of Defense has received implementation plans from the Services.

Recommendation 4-2: Greater Reliance on Peer Review

In the case of basic research, the involvement of DOD laboratories is small—about 4% of their total funds or roughly $240 million out of $6 billion worth of RDT&E. About $60 million or 1% of the total funds are provided to laboratory directors as discretionary funds to be used for investments in scientific areas the directors deem important, or to increase laboratory expertise in selected technical areas. In this latter case, the quality of completed work is used as a factor in distributing new discretionary basic research funds.

Peer review will continue to be used to evaluate the quality of completed basic research projects. Quality is a factor but not the only factor in determining whether or not new basic research projects will be funded. Relevance to mission as well as success in transitioning research results to further development are also factors that will be considered.

Recommendation 4-3: Finite Term for Laboratory Director

Most DOD laboratory directors are military personnel. They normally serve 3-year terms. The civilian laboratory directors are members of the Senior Executive Service (SES) and already can be (and frequently are) moved to another position as management sees fit. The performance of the director and the laboratory are significant factors in such decisions.

This recommendation has been implemented to a great extent but is still reviewed periodically. A study of the Army laboratories had two specific recommendations regarding the appointment of directors. These are being reviewed by senior Army management.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

Present DOD policy is to encourage the use of its unique laboratory facilities by universities when they are not being used to perform the laboratories' missions. The manner in which these facilities can be used

by non-DOD investigators is prescribed by DOD Directive 3202.1 and DOD Instruction 7230.7. Work will be performed for private industry when a DOD laboratory possesses unique facilities not available in the private sector. (See DEPSECDEF Memo, January 21, 1972.)

Extensive efforts are under way to facilitate DOD-university-industry interactions in both research and education. Over the past 4 years, more than 2,000 high-school students have had summer research experiences/apprenticeships in DOD laboratories or with university research under contract to DOD. In the summer of 1984, DOD will test a new program, modeled after the DOD High School Apprenticeship Program, to enable high-school science and mathematics teachers to have summer research experiences in DOD laboratories to enhance their teaching skills.

DOD has established a formal advisory body, the DOD-University Forum, which discusses issues of mutual interest to DOD and academia. One of the Forum's working groups recently completed a major report on engineering and science education. The report examined DOD's needs for trained technical personnel and made recommendations of importance to scientific and engineering personnel employed in DOD laboratories. At the undergraduate and graduate levels, DOD laboratories employ approximately 800 co-op students a year. DOD is currently examining the feasibility of providing scholarship support to co-op students. DOD's basic research programs support approximately 4,000 graduate assistants each year. In addition, each Service has established graduate fellowship or assistantship programs which this year will support almost 200 students pursuing advanced degrees in disciplines important to the defense mission. Many of these students also have summer DOD laboratory research experiences.

DOD also sponsors summer faculty research opportunities in DOD laboratories for university researchers. In 1983 more than 300 faculty members as well as some 50 graduate students conducted summer research in DOD laboratories. Participants in Air Force programs are also eligible to apply for mini-grants to continue DOD-related work during the school year.

The DOD University Research Instrumentation program will help universities buy $150 million in research equipment by fiscal year 1987. DOD, together with several major corporations, is also supporting the new National Technological University, a consortium of 24 major engineering schools, which will deliver advanced engineering degree coursework via satellite to industrial and DOD laboratories by 1985. DOD will continue to encourage use of its facilities by universities and will continue to strengthen its interactions with education at all levels.

Recommendation 5-2: R&D Interaction between Federal Laboratories and Industry

---

R&D interactions between DOD laboratories and industry are commonplace. Industry supplies the Nation's weapons and works with DOD labo-

57-279 O - 87 - 58

ratories as a matter of course in producing the means for our defense. This buyer-seller relationship with industry makes industry funding of DOD laboratories inappropriate, because DOD laboratories must evaluate the seller's products. Industry funding in DOD laboratories would create a potential conflict of interest, and the appearance of a conflict would always be present.

There are now several DOD activities aimed at improving interactions and information exchange between DOD and private industry. Information liaison offices have been set up by the Services nationwide to provide information on DOD operations and interests to DOD contractors. In response to the Stevenson-Wydler Act, every DOD laboratory now has an Office of Research and Technology Application (ORTA). The ORTA is a point of contact which provides information on the laboratory's technical activities to those outside of DOD and is responsible for assisting in technology transfer to state and local governments and to private industry. DOD representatives also interact closely with industry researchers in reviewing industry's Independent Research and Development (IR&D) Program. Through the Defense Technical Information Center and DOD's Information Analysis Centers, DOD research results are made available to DOD's present and potential contractors.

The Small Business Innovative Research Act requires that a percentage of all DOD research funds be set aside for this highly innovative segment of private industry. Funding decisions on small-business research proposals are made at the project-manager level, thus encouraging additional interactions.

Other examples of DOD activities promoting interactions include the tri-Service Information for Industry offices in Alexandria, Virginia, Dayton Ohio, and Pasadena, California, and the participation of both industry and university personnel on the Defense Science Board and the Scientific Advisory Boards of the Services. The latter are being given the additional role of evaluating the performance of DOD laboratories. DOD is committed to continuing its extensive interaction with private industry.

Recommendation 5-3: Simplified Federal Procurement Procedures

A permanent working group of procurement specialists has been established within the DOD Laboratory Management Task Force (LMTF) to simplify procurement procedures on a continuing basis. Another group is concentrating on simplifying the contracting procedures for the Small Business Innovation Research Program with the aim of using the procedures as a model for other procurements. In addition, a report has been prepared entitled, "Actions Required to Improve Research and Development Procurement and Contracting."

Recommendation 5-4: Support to Military Operating Forces

A task force formed by the Office of the Secretary of Defense is considering new approaches to provide closer coupling of the Service labora-

tories with the operating forces. The task force has identified a number of Service programs wherein the laboratories provide support to the operating forces.

The Army Materiel Development and Readiness Command (DARCOM) has a number of programs to identify requirements for R&D support of the operating commands. Teams of DARCOM scientists regularly conduct fact-finding missions to field units for the purpose of identifying problems in the operational use of communications equipment requiring R&D solutions. DARCOM maintains 19 detachments of on-site liaison representatives at Army training centers and schools to identify problems requiring R&D support. These needs are communicated directly to the appropriate DARCOM laboratories.

The Naval Material Command co-locates approximately 30 scientists and engineers on a rotating basis with their operational commands under the Navy Science Assistance Program. The rotational assignments provide the scientists and engineers with operational experience and improve communications with the laboratories in operational problems.

The Air Force has a variety of procedures for identifying the R&D needs of the operating commands. Formal documents to identify logistics needs, research needs, and R&D objectives are developed through cooperation among the Air Force Logistics Command, the Air Force Systems Command, and the operational commands. The Strategic Air Command hosts an annual, week-long conference with laboratory participants to identify R&D objectives and to foster informal cooperation. The Tactical Air Command has a point of contact for each development-program element and is consulted for comments on relevant exploratory and advanced development programs. The Chief Scientist of the Air Force has initiated a program whereby the chief scientists of Air Force organizations meet twice a year at locations of the operating forces. The goal of these meetings is to enhance interactions between the operating forces and the Air Force R&D community.

The laboratories' External Advisory Groups will be requested to include support of operating forces among the important criteria against which they measure the performance of the DOD laboratories.

DEPARTMENT OF ENERGY

MISSION

Recommendation 1-1: Mission Review

On July 28, 1983, as part of the institutional planning process for fiscal year 1984-fiscal year 1989, Secretary Hodel issued the Department of Energy's (DOE's) policy guidance on the role and missions of the multiprogram laboratories. The Secretary's policy guidance is based on his Congressional statement on the Federal role in energy R&D and is consistent with the National Energy Policy Plan.

On February 15, 1984, the Laboratory Management Council (LMC) developed a generic laboratory role statement and reviewed and revised all proposed laboratory mission statements with special attention to their clarity and specificity. In addition, the programs have been urged to develop 5-year program planning guidance and mission area assignments for the laboratories and to appraise laboratory program performance regularly.

Beginning in 1984, annual laboratory appraisals will be carried out by the cognizant Operations Office to evaluate overall laboratory performance in carrying out their assigned missions. The Headquarters program performance review will be part of the overall laboratory management appraisal.

Recommendation 1-2: Size of Laboratory

The institutional planning process of the Department results in review of laboratory workload consistent with missions and quality of work. The budget process determines increases or decreases in laboratory work depending on the quality of the past year's work, and any overall change in missions or directions made as a result of Administration or departmental policy. For example, recent mission redefinitions have resulted in significant decreases in laboratory size in the area of applied technologies, particularly those viewed as having near-term commercial benefits.

The multiyear program plans will provide an appropriate foundation for long-term mission area assignments to laboratories, justification for stable multiyear budget authorizations, and a sound basis for a more effective 5-year institutional planning process. Although they are limited in controlling fluctuations in budgets, the Assistant Secretaries will encourage long-term mission area commitments to laboratories and continue to give high priority to minimizing budget fluctuations. DOE's Internal Review Budget crosscuts will be used to control fluctuations in the planning stage, and ensure proposed laboratory program budgets do not fluctuate randomly without management attention.

The Laboratory Management Council, as part of its consideration of laboratory 5-Year Institutional Plans will review the proposed size of laboratories based on approved missions. As part of the Internal Review Budget procedures, the LMC also reviews proposed budgets of multi-

program laboratories to encourage stability consistent with mission needs and resources, and for consistency with mission statements, and appraisals of performance. The LMC will bring problems to the attention of the Secretary for resolution.

PERSONNEL

Recommendation 2-2: Independent Salary Administration for Government-Owned Contractor-Operated (GOCO) Laboratories

DOE laboratories are responsible for exercising management judgment and discretion in the administration of employee wage and salary programs. DOE retains only the right to approve a limited number of top level salaries and annual salary increase funds before such actions are implemented. DOE approval is based on data that the contractor itself develops as basis for its decision making purposes and that show the action to be consistent with programs in the private sector.

DOE now plans to delegate approval authority to the laboratories for salaries up to $60,000.

DOE develops internal guidance to be used in determining the reasonableness of laboratory personnel compensation costs. Such guidance was recently updated and will continue to be revised to reflect current compensation trends for employees with comparable jobs in appropriate labor markets. Experience in the private competitive economy is used as the primary standard of reasonableness with no reference to Civil Service compensation levels.

DOE will periodically review the threshold levels for individual salary approvals to ensure there is no increase in the percentage of total salary actions reviewed. DOE will also continue to refine and clarify criteria for market-basing of salary structures, so that laboratories will be able to make periodic adjustments with only minimal discussions with DOE.

FUNDING

Recommendation 3-1: Multiyear Funding

Taken literally, the recommendation does not call for funding stability but for funding *predictability*, so that staffing and research levels at laboratories can be properly planned. Much of the apparent instability in DOE laboratory funding in recent years has been a direct result of the Administration's effort to focus the laboratories on longer term programs and projects more appropriate to DOE's R&D mission, and away from near-term, more developed technologies that are properly the responsibility of the private sector.

Greater predictability of funding could be enhanced by multiyear authorization and appropriation of funding. Failing that, funding predictability could be improved by measures to better ensure the passage of annual Congressional appropriation bills prior to the end of the fiscal year.

The DOE has secured multiyear authorizations from Congress and hopes to do so again. However, the House Rules Committee and the

Senate Government Affairs Committee may recommend a 2-year authorization and appropriation cycle to the Congress, presumably as amendments to the Budget and Impoundment Control Act of 1974. If the Congress does not approve the proposed action, some improvements could be gained through greater use of multiyear program planning documents, cleared by the Office of Management and Budget and sent to Congress for comment and "approval," or inclusion of report language with the annual appropriation bills that would explain the position of the Appropriations Subcommittee regarding the future direction and funding profile of certain basic and applied research programs. Unlike multiyear appropriations, neither of these partial solutions would provide funds or have the force of law, but they would at least be expressions of Congressional intent and might provide some additional measure of predictability to the management of R&D.

Recommendation 3-2: Discretionary Funds

In a policy statement issued on December 13, 1983, Secretary Hodel clearly established policy for use of funds for exploratory development at multiprogram laboratories. Under this policy, laboratories are allocated reasonable amounts of funds, and laboratory directors exercise authority in choosing projects for funding. Laboratory work is scrutinized at an annual review of institutional planning, where the highest management level looks at both the process and the results of such funding. Those laboratories that do well in carrying out the general goals of exploratory R&D funding (e.g., spurring research vitality, generating new ideas, attracting talented scientists) receive increased funding.

Prior to the issuance of this policy statement, there were similar discretionary funded efforts, but without central and consistent guidance. The current procedure for such funding is clear and consistent with the Packard Report recommendations. The percentage of exploratory R&D funds is expected to range from about 1% to 5%.

Recommendation 3-3: Carry-over Funding

DOE appropriations for research and development are no-year funds. Therefore, no change in funding is necessary to meet the recommendation.

MANAGEMENT

Recommendation 4-1: Oversight Function

The Laboratory Management Council is reviewing ways of implementing the recommendation by utilizing existing mechanisms where effective and modifying processes where necessary. Oversight panels exist for Argonne National Laboratory (ANL) and Brookhaven National Laboratory (BNL), and one was recently included in the new Oak Ridge National Laboratory (ORNL) contract. Weapons laboratories have similar panels reporting to the University of California. Plans are being developed to

ensure that these groups can and will effectively perform the required oversight functions.

Recommendation 4-2: Greater Reliance on Peer Review

The proposal preparation and approval process within the laboratories has many elements comparable to traditional peer review, including review by advisory committees to the laboratories. Areas such as high-energy physics have extensive peer review of research results prior to and including the publication process. Furthermore, DOE carries out results-oriented peer reviews of major laboratory research programs compared to similar research in universities (e.g., the 1982 Assessment of Basic Energy Sciences Programs). Several efforts have also been made toward relying to a greater extent on peer review evaluations in funding specific energy research programs at the laboratories.

In addition, a working group of affected program offices has been established to propose guidance on how best to accomplish peer review of basic research at the laboratories. The Laboratory Management Council will review the proposed actions in 1984 and recommend any necessary changes in departmental policy in this area.

Recommendation 4-3: Finite Term for Laboratory Director

A DOE Order on uniform laboratory appraisal was issued on October 6, 1983. It requires annual, results-oriented appraisals at all the major multiprogram laboratories. The Operations Office appraisals will include laboratory director accountability, but the prime responsibility for laboratory performance will continue to remain with the contractor. Review of director's accountability when coupled with contact extend/compete decisions (which occur every 5 years) will result in a process that meets the objective. In the last 5 years, new directors have been appointed at 7 of the 9 major multiprogram laboratories.

Recommendation 4-4: Congressional Oversight of DOE

Compared to other departments, DOE has had the most changes in missions in the past 7 years evolving from the Atomic Energy Commission, to the Energy Research and Development Administration, to the Department of Energy. In a letter on July 28, 1983, Secretary Hodel issued the Department's policy guidance on the missions of DOE and its multiprogram laboratories. The Secretary's policy guidance is based on his Congressional statement on the Federal role in energy R&D and on the National Energy Policy Plan IV which was published and forwarded to Congress in October, 1983.

Recent stabilization in renewable energy programs and reductions in commercialization-related activities, coupled with the National Energy Policy Plan and the Secretary's statement on Federal and DOE labora-

tories roles, have put the Department in the best position to date to communicate and affirm DOE missions and to participate in discussions with Congress regarding DOE oversight and reduction of the number of Congressional committees with budget and oversight responsibilities for DOE programs.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

Secretary Hodel's policy guidance to the laboratories endorses the recommendation and encourages the laboratories to improve accessibility to facilities by universities and industry. The Secretary has assigned a generic role to the laboratories to provide appropriate use of the laboratories' major capital-intensive facilities to the scientific community.

The laboratories continue to be important complementary resources to university-based research and education. About 5,000 university faculty members and students participate each year, generally during the summer, in laboratory-sponsored research and training programs. The budget for the DOE University Laboratory Cooperative Program has been significantly increased in fiscal year 1985 to support additional faculty/student research appointments. Significant funding continues for operation of major user-oriented research facilities at the laboratories; for example, about 40% of the Basic Energy Sciences budget in fiscal year 1985 will support laboratory research facilities which are used by university scientists. In fiscal year 1985 the number of undergraduate students in summer programs at the DOE laboratories will double, from 600 to 1,200. In addition, the laboratory directors have been encouraged to increase support for post-doctoral research appointments and for faculty "sabbatical" year research.

A "User's Guide to DOE Facilities" was published in March 1984 to provide information about unique laboratory facilities available to industry and universities for conducting their own research on-site at the laboratories using equipment available only at DOE laboratories. There are significant examples of industry and university participation in the planning for and use of the facilities such as the Combustion Research Facility at Sandia National Laboratories (Livermore), and the National Synchrotron Light Source at Brookhaven National Laboratory. To further encourage use of DOE facilities by universities and industry, the Department has issued a class patent waiver covering data and patent rights to discovery and inventions made by users of such facilities. The response has been an increase in user interest and participation.

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

DOE has implemented an R&D Technology Transfer Program responsive to the Stevenson-Wydler Act (P.L. 96-480). This program establishes DOE policy that technology-transfer activities, as required by P.L. 96-480, are legitimate functions of the R&D laboratories and will be conducted. To

meet both the spirit and the intent of P.L. 96-480, the Department has also issued guidance to the laboratories encouraging consulting by laboratory personnel. Such activity has increased as a result. Also as a result, technology-transfer activities at the laboratories have increased, and the Department, in consultation with the laboratories, has identified barriers to technology transfer and has addressed them. The Department will continue to identify barriers to technology transfer and to resolve them in the future. A senior-level working group has been established to review the Department's work-for-others policy and procedures to facilitate interactions with industry.

Secretary Hodel has assigned generic roles to the laboratories as follows: (1) to provide for and encourage the transfer of technology developed at the laboratories to the private and public sectors, and facilitate an interactive climate among the national laboratories and industry; and (2) to make special capabilities available for public and private sectors on a reimbursable basis. Personnel exchange programs between industry and laboratories, as well as industry-funded work-for-others projects, are being encouraged.

The laboratories have established a close relationship with the Industrial Research Institute (IRI) to stimulate interactions. A series of "Spotlight on a Laboratory" reports in cooperation with IRI has been initiated to encourage industry access to facilities and to communicate work of potential commercial interest. Industry reaction has been quite favorable so far. To further encourage R&D interactions, DOE has issued a class patent waiver for inventions arising from reimbursable work-for-others and for work at DOE user facilities. The response has been an increase in interactions with industry.

Recommendation 5-3: Simplifying Federal Procurement Procedures

---

Regarding university contracting procedures used in DOE, a working group has been established to recommend ways to simplify these procedures. As part of this process, DOE is converting many university awards from contracts to grants. Also, emphasis has been placed on consistent interpretation of DOE university procurement regulations and procedures by all field elements.

In the contracting area, the Operations Offices, not the GOCO laboratories, are agents for the Department. Special attention is paid to ensuring that the laboratories are not used as "pass-through" mechanisms or as a way to bypass the Federal procurement process. The laboratories do, when assigned, act as technical managers for projects, which includes appropriate subcontracting to industry and universities. Subcontracting by the laboratories in 1983-1984 was approximately $1 billion.

DEPARTMENT OF HEALTH & HUMAN SERVICES: NATIONAL INSTITUTES OF HEALTH

MISSION

Recommendation 1-1: Mission Review

The mission of the National Institutes of Health (NIH) is to improve the health of the Nation by increasing the understanding of processes underlying human health, disability, and disease; by advancing knowledge concerning the health effects of interactions between man and the environment; and by developing and improving methods of preventing, detecting, diagnosing, and treating disease.

NIH accomplishes this mission through: support of biomedical research in universities, hospitals, and research institutions in this country and abroad; conduct of biomedical research in its own laboratories and clinics; support of training for promising young researchers; development and maintenance of research resources; identification of research advances that have significant potential for clinical application, and the facilitation of the transfer of such advances to the health care system; and promotion of effective ways to communicate biomedical information to scientists, health practitioners, and the public.

New organizational or administrative entities have been established in response to changing aspects of the NIH mission; notable examples are the Office for Medical Applications of Research (OMAR) in 1977, and the National Toxicology Program (NTP) in 1978.

The Director of NIH, utilizes the Advisory Committee to the Director as a high-level outside consultative body to discuss management issues. Currently, the elements encompassed in pursuit of the primary NIH mission are being examined by a committee of the Institute of Medicine of the National Academy of Sciences, which is conducting a "Study of the Organizational Structure of the National Institutes of Health." Three panels are addressing the following aspects: historical issues, current organization, and alternatives. The Alternatives Panel's considerations include (1) "scientific opportunity" and "burden of illness" as criteria for setting research priorities, (2) the balance between basic and targeted research, (3) the balance between intramural and extramural research, (4) the balance between funding mechanisms such as grants and contracts, and (5) how to promote and stimulate priority or neglected research areas.

Recommendation 1-2: Size of Laboratory

The NIH is composed organizationally of 11 different institutes and several research divisions. These components support research extramurally through grants and contracts to outside organizations, principally universities. Most also conduct an in-house research program, called intramural research. The latter accounts for 13 percent of the R&D budget.

The emphasis, intramurally, is in basic research, which has possibilities of ultimate payoffs far in the future (e.g., advances made possible by the recombinant DNA biotechnology revolution), and on research better adapted to an in-house type of operation (e.g., long-term research on slow viruses and follow-up of an aging population over a lifetime). Such basic research is essentially limited by the magnitude of resources available.

A variety of indicators of quality of research effort all point to the premier status of the intramural program. There is the recognition by outside awarding bodies (4 Nobel Prizes, numerous Lasker Awards, etc.), the highly favorable citation and publication analysis, and the disproportionately large number of academic and investigative leaders throughout this Nation and the world who received research training at NIH (NIH "graduates").

While it is regarded that the intramural program has achieved a reasonable size for the present, there will from time to time be limited expansion dictated by external factors, such as the proposed new Arthritis Institute. In cases of significant resource additions, most program expansion will, of necessity, occur in the extramural area, owing to space or full-time-equivalent position constraints.

The NIH agrees that the size of its laboratory operation should be appropriate to its missions and the quality of its research. As new health demands and new scientific opportunities develop, the NIH will do its best to mobilize the resources for expanded intramural and extramural programs. Growth, if and when it takes place, should be gradual enough to be sustained.

FUNDING

Recommendation 3-1: Multiyear Funding

NIH funds are appropriated on an annual basis. With regard to pay raises, the Congress may appropriate supplemental funds for all or part of the pay raise, may approve a transfer from another appropriation, or may provide no dollars and require NIH to absorb the cost.

NIH supports a 2-year appropriation for both in-house and extramural research, and is in favor of a pay raise appropriation.

Two-year appropriation would require modification to the appropriation language for each NIH account and approval by Congress. The Office of Management and Budget (OMB) and Congress must approve pay raise appropriation.

Recommendation 3-2: Discretionary Funds

The NIH intramural research program is executed under the discretion of the director and scientific director of each of its institutes in accordance with the broad program goals and objectives of the Administration and Congress, and thus is considered to be 100% discretionary.

No change in funding is necessary to meet the recommendation.

Recommendation 3-3: Carry-over Funding

NIH has 1-year obligation authority; no carry-over authority.

NIH recommends that 1% of total appropriations be permitted to be carried over for 90 days.

Appropriation language for each NIH account would require modification and approval by Congress.

MANAGEMENT

Recommendation 4-1: Oversight Function

Excellence of a laboratory is determined largely by the quality of an individual scientist's research. The determination of quality includes the evaluation of original publications in the scientific literature (their impact on an area of science can be assessed in a quantitative way by citation analysis) and the recognition accorded a scientist by peer groups (evidenced by election to prestigious societies, receipt of prizes or awards, or other measures of "standing" in a scientific field). An intramural scientist's research is reviewed (1) by external Boards of Scientific Counselors at least every 4 years, (2) by the NIH Board of Scientific Directors at a time when the scientist is considered for tenure or promotion, and (3) by the laboratory and branch chiefs on an annual basis. The first two of these processes, as described below, represent external reviews with respect to each component Federal laboratory.

Recommendation 4-2: Greater Reliance on Peer Review

The NIH intramural research programs are, in a very real sense, critically reviewed by peers from outside the Federal Government, on a fixed schedule, with important implications for the size and direction of the programs and for the funding and other support for individual laboratories and scientists. (See comments on previous recommendations.) Each institute has its Board of Scientific Counselors for this review purpose.

NIH does not view the "competitive peer review process" as the proper mechanism for dealing with in-house staff. An ongoing process of review and evaluation is more appropriate to an operation in which one's own employees are engaged in research, as contrasted with extramurally supported grantee or contractor projects.

Recommendation 4-3: Finite Term for Laboratory Director

Within the framework of the NIH Intramural Programs, this management consideration related to the scientific directors, and to the laboratory and branch chiefs. The specific projects within each laboratory and branch are reviewed at least every 4 years by the outside Boards of Scientific Counselors and annually by the scientific director.

A scientific director of an NIH institute or division is jointly accountable to the institute director and to the NIH Deputy Director for Intramural Research regarding quality, productivity and program relevance. On several

occasions in the past, a scientific director has been replaced because of inadequacies in performance. Similarly, laboratory or branch chiefs are accountable to scientific directors and may be replaced as necessary.

A proposed new pay and personnel system for NIH scientists (pertinent to Recommendation 2-1 of the Packard Report) has been developed, first, by the Committee on Pay and Personnel Systems in Intramural Research and, second, by the NIH Committee on Pay of Scientists. These two committees recommended consideration of renewable (e.g., 5-year) terms for laboratory/branch chiefs (after age 70, renewable annually).

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

By far the largest part of the NIH budget is devoted to support for extramural research performed principally at universities. In 1985, research project grants initiated by investigators amounted to $2.7 billion.

The academic community is provided access to NIH intramural laboratories and clinics through Guest Researcher appointments and via a number of temporary-type personnel mechanisms, such as Experts, Intergovernmental Personnel Act appointees, summer employment, etc. The NIH will continue to provide the opportunity for academic researchers to take advantage of the unique facilities, equipment, or expertise of the NIH intramural laboratories and clinics.

NIH has no policy that would preclude an industry employee from participating at NIH under a Guest Researcher appointment, provided that a determination was made that no conflict of interest existed and that planned research was consonant with the goals of the host laboratory. However, the relatively small number of industry scientists who have been Guest Researchers may be due to concerns that their proprietary interests would be jeopardized by signing the Guest Researcher Agreement. This document requires adherence to Executive Order 10096 with regard to any inventions conceived or actually reduced to practice in performance of the scientists' work at NIH. In fact, however, recent changes in Federal patent policy make cooperative ventures between the public and private sectors more attractive. A Committee on Joint NIH-Private Sector Endeavors, chaired by the Deputy Director of NIH, has formulated a set of general principles for participation in joint projects. An "inventory" of such projects will be maintained for reporting and monitoring purposes.

The Foundation for Advanced Education in the Sciences (FAES) at NIH is a private institution chartered in the State of Maryland. In collaboration with the Johns Hopkins University, a formal Ph.D. curriculum has been established wherein the students take their course work at Johns Hopkins and do their thesis research at NIH, under an NIH intramural scientist preceptor.

Through its extramural research and training programs, the NIH supported over 5,000 post-doctoral trainees in fiscal year 1983. Some of these individuals will select the intramural NIH laboratories and clinics as the location for their training. In addition, the staff fellow program brings many junior-level scientists to NIH for temporary appointments ranging from 2 to 7 years. A small fraction will ultimately be offered a permanent

position at NIH; the majority will assume positions in the private sector, typically in academia, but now increasingly also in the biotechnology industry.

The NIH Scientific Faculty, suggested as the new personnel system for scientists at NIH, proposes to use the TIAA-CREF retirement system which is in use at most universities. Availability of this option would create more opportunities for mobility between NIH and the academic sector (perhaps several times during a career).

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

---

Technology transfer at NIH was given formal recognition in 1977 with establishment of the Consensus Development Program. The Office for Medical Applications of Research was created in the Office of the Director to serve as its administrative focal point.

The Consensus Development Program has three primary objectives: (1) to provide a setting for the evaluation and review of the scientific soundness of a health or health-related technology, with emphasis on safety and efficacy; (2) to aid in the diffusion of knowledge of advances in biomedical technology through dissemination of the findings from the consensus development process to physicians and the consumers; and (3) to facilitate the diffusion, adoption, and appropriate use of those technologies found to be sound.

To date, nearly 50 statements on topics ranging from the treatment of breast cancer to the removal of third molars have been distributed. Consensus statements are produced by persons outside the Federal Government and are designed to serve as guidelines for the physician and the patient. The emphasis is placed on scientific evaluation, but social and economic considerations can have an impact in the assessment of a given technology. As a result of consensus development evaluations, it is hoped that the use of those technologies found to be scientifically sound will increase, and that the use of those that receive no such endorsement will diminish, thus improving the quality of health care.

The Committee on Joint NIH-Private Sector Endeavors has articulated general principles to guide the establishment and conduct of joint activities with commercial organizations. Issues to be considered include (1) the programmatic importance of the project to NIH, (2) the reasons for pursuing partial or total outside support, (3) the scientific integrity of a jointly sponsored research project (e.g., data management, quality control, decisions to modify protocol, release of study results), (4) the integrity of NIH (e.g., implied endorsements, advertisements), (5) the accuracy of scientific information to be disseminated, and (6) legal and policy issues (e.g., patents, gifts, solicitation of contributions, conflicts of interest, peer review).

A number of patented inventions made in NIH laboratories have been licensed to industry. Most licenses (some 54, through July 1983) awarded were non-exclusive, although 10 exclusive licenses were also granted during this period. Inventions include newer biotechnology advances (e.g.,

monoclonal antibodies against various viruses), analytical techniques (e.g., fiber-optic pH, oxygen and carbon-dioxide sensors, countercurrent extraction and chromatography instruments), and therapeutic modalities (e.g., anti-cancer agents). A recent formal agreement between Damon Biotech, Inc. and the National Cancer Institute (NCI) illustrates the kind of mutually advantageous arrangement that can be worked out between government and industry. In the latter case, Damon possessed proprietary knowledge of certain encapsulation technology, including biological materials and living cells within semi-permeable membranes. The NCI wished to explore the possible advantage of such technology in cancer research.

DEPARTMENT OF THE INTERIOR: U.S. GEOLOGICAL SURVEY BUREAU OF MINES

MISSION

Recommendation 1-1: Mission Review

USGS:

The Director of the U.S. Geological Survey (USGS) has indicated that laboratory research will support USGS missions. Program reviews and evaluations have been the major method of determining laboratory objectives.

The present planning and budget formulation process will continue to be the method by which laboratory mission and program mission are linked. During the planning process, new programs and new initiatives to expand are proposed. These are reviewed at the division and directorate levels in terms of their authority in supporting the missions of the USGS as defined by the Organic Act and subsequent legislation. These initiatives when proposed in the budget process are reviewed by the Department of the Interior, the Office of Management and Budget (OMB), and Congress in terms of their contribution to USGS mission objectives.

BOM:

Each of the four mining research centers in the Bureau of Mines (BOM) has been designated as the lead center for certain mining research areas. Mission statements defining the role of the mining research centers have been prepared. The mission of each of the six minerals and materials research centers has regularly been examined to assess the need for redefinition in keeping with the overall mission and goals of the Bureau.

The Bureau of Mines makes the special capabilities and expertise of the laboratories available to others, consistent with current policy and regulations.

Recommendation 1-2: Size of Laboratory

USGS:

USGS has relied specifically on the planning/budget formulation process to determine the size of its laboratories.

USGS has found that the current planning/budget formulation process is a very effective means of determining optimal laboratory size. USGS will continue to use this process. Although the total budget will have a significant impact on the size of laboratories, other factors relating to mission and other agency requirements will be influential.

BOM:

The scope of Bureau research depends upon national priorities. Thus, the size of Bureau research centers has changed with changing scope.

For example, as the role of Federal research evolved from developmental to more basic research, the pilot plant facility at Boulder City, Nevada, was closed in fiscal year 1983. In an earlier example, when the goals of a cooperative experimental ironmaking blast furnace were reached, the steel industry and the Bureau concurred in closing the facility.

FUNDING

Recommendation 3-1: Multiyear Funding

USGS:

Funds are appropriated on an annual basis, with no separate appropriation for research.

USGS supports R&D funding on a 2-year basis if that funding is predictable. The appropriation would have to allow for increases for pay raises, cost-of-living allowances, and supplementals for unforeseen circumstances of a significant nature.

No agency action is required until the Executive Branch (represented by the President's Science Advisor and the Office of Management and Budget) and the Congress jointly agree to the funding recommendation.

BOM:

As an agency of the Administration, the Bureau must conform to Administration policies and is unable to anticipate Congressional actions. Therefore, plans for the affected programs have been made only after Congressional intent is clear. This has resulted in delays in program implementation and in obligating the added funding.

Recommendation 3-2: Discretionary Funds

USGS:

USGS basic earth science research is conducted within the broad program goals and objectives of the Administration and Congress and is considered to be completely discretionary. Research projects and publication of results are reviewed through a process of peer review and executive approval which maintains the highest scientific standards.

No change in funding is necessary to meet the recommendation.

BOM:

Pioneering research has been an established practice. For the last 30 years the BOM has authorized the use of up to 10% of its R&D funds for this research in-house. The efforts are periodically reviewed by research center management and the more promising efforts become formal research projects after review and approval by Headquarters management. Funding of cooperative research programs with universities and industries is constrained by Federal procurement regulations.

57-279 O - 87 - 59

Recommendation 3-3: Carry-over Funding

USGS:

USGS has 1-year obligation authority; no carry-over authority.

The USGS recommends that 1% of total appropriations be permitted to be carried over for 90 days.

Appropriation language for the USGS account, including research funded by reimbursement, requires modification and approval by OMB and Congress. As part of the 1986 budget process, the USGS will seek carry-over authority from Congress through appropriate Department of the Interior channels to OMB.

The 1986 USGS preliminary budget to the Department of the Interior will contain a request for carry-over authority.

BOM:

The Bureau of Mines follows OMB guidance.

MANAGEMENT

Recommendation 4-1: Oversight Function

USGS:

Ongoing internal program evaluations include laboratories. USGS scientists frequently coordinate research efforts with universities and other governmental units. Periodic meetings with state geologists provide considerable input to the USGS regarding relevance of research efforts to public needs. Other formally established advisory groups make recommendations to USGS, which, in turn, affect research at the laboratory level. These are the advisory groups established to implement USGS delegated coordination responsibilities under OMB Circular A-16, (coordination of National and state mapping requirements), and A-67 (coordination of Federal and non-Federal water data and analysis activities). Specifically for geological programs, there is a committee advisory to the USGS under the aegis of the Board on Earth Sciences of the *National Academy of Sciences/National Research Council* (NAS/NRC).

USGS is continuously examining ways to increase the effectiveness of its laboratories. There will be a continued effort to make use of advisory and peer groups that represent educational, industrial, and other government sectors.

BOM:

The performance of the research centers is evaluated by the two assistant directors responsible for research. Technical personnel from the Mine Safety and Health Administration periodically review and evaluate the Bureau's Mine Health and Safety Research Program. There have also been several reviews of important parts of the Bureau's research program by committees of the National Academy of Sciences with strong industry and university representation. Any tendency toward micromanagement has been decreased by cutting in half the size of the Headquarters research management staff during the past 2 years. Changes have

been made in the procedures for review of on-going mining research projects which also should help prevent micromanagement of the research centers by Headquarters staff.

Recommendation 4-2: Greater Reliance on Peer Review

USGS:

As part of the annual program/budget development process, the USGS laboratories outputs and accomplishments are peer reviewed. Each research project is reviewed at the first level of supervision several times per year to assure that the project is accomplishing its objectives. Ad-hoc committees are appointed at higher levels as necessary to review specific programs. The many publications that are published in external journals receive extensive peer review by scientists from other research sectors.

The USGS plans to continue its present review practices. They have been found to be effective in ensuring products of a high quality and a high level of productivity that reflect the missions of the survey.

BOM:

There is competitive review of all proposals for contract research. Proposals for new in-house research projects are evaluated and prioritized by committees of technical peers from the research centers and Headquarters staff. Technical personnel from the Mine Safety and Health Administration provide half the members of the committees that evaluate proposals or in-house research on mine health and safety.

Recommendation 4-3: Finite Term for Laboratory Director

USGS:

The Director of the U.S. Geological Survey is a political appointee and serves at the pleasure of the President. Appointment of directors since the establishment of the USGS in 1879 has been done in consultation with the National Academy of Sciences. The procedure of recent years has been for NAS, at the request of the Secretary of the Interior, to organize a nominating committee of leading earth scientists. The committee prepares a list of nominees in priority order from which the Secretary makes his selection.

BOM:

BOM research centers directors are at GM-15 and Senior Executive Service (SES) levels. They are responsible to an assistant director at Headquarters and are subject to individual performance plan standards. During the past decade, several research center directors have been placed in less critical positions when their performance was judged less than fully satisfactory by higher Bureau management.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

USGS:

Throughout its more than 100-year history, the USGS has encouraged close interactions with universities and industry through mutual research and sharing of laboratory facilities. A NAS/NRC committee consisting of people from industry and academia exists partly to facilitate such interactions. The USGS will continue to implement new recommendations from this committee. Cooperative projects will continue to be looked at on a case-by-case basis.

The USGS will continue to make the special capabilities and expertise of the laboratories available to others, consistent with current policy and regulations in this area. Examples of USGS facilities used by university personnel include the TRIGA reactor, electron microprobes, transmission electron microscopy, and mass spectrometers. Research in mineral and energy resources with industry is rather inhibited because of proprietary problems. An exception is the USGS Core Library in Denver which stores samples of cores from wells drilled principally in the western and central United States. Approximately 400 visitors from industry use the facility each year.

In addition to more formal arrangements with the academic community listed below, the USGS and academic scientists carry on a continuous dialogue through the usual channels. Many joint publications are written, involving no transfer of funds. The USGS employs about 150 university professors on a when-actually-employed basis and is thus able to utilize the talents of some of the more gifted academic researchers for its mission.

The USGS has traditionally played a strong role in education in the geological sciences. Examples are:

About 10 National Research Council postdoctoral fellows are in residence at any given time.

The USGS employs from 50 to 75 undergraduates as field assistants each summer, through a formal arrangement with the National Association of Geology Teachers. Four hundred students compete for the positions each year; graduates of the programs are especially desirable to oil companies, who allocate extra points to them in their rating system.

Two hundred other summer jobs are given to students each year under regular summer-employment programs. Many of these positions also are field assistantships.

Graduate internships are given to some 30 M.S. and Ph.D. students. They are funded for actual time worked, and many derive a thesis from their work. Full use of laboratory facilities is available to them. About two permanent positions per year are allocated to graduates of this group. In addition, the USGS participates in the Federal Junior Fellow Program by placing 70 talented, college bound, high school graduates who are interested in careers in governments.

A plan is being drawn up for a USGS lecture program at historically Black colleges and universities. In addition, research projects were funded at two of these institutions in fiscal year 1984.

A number of students use USGS facilities for thesis work on an ad-hoc, non-employment basis.

Over 50 USGS employees serve as Adjunct Professors around the country and teach evening courses; many more lecture at universities on invitations.

BOM:

The Bureau of Mines has always encouraged close interactions with universities and industry through mutual research and sharing of laboratory facilities. Most BOM laboratories are located close to university campuses and maintain an active association with those institutions, with joint use of laboratories. Industry personnel have historically had the use of BOM laboratories in cooperative studies.

The BOM will continue to make special capabilities and expertise of the laboratories available to others, consistent with current policy and regulations in this area. Cooperative projects will continue to be looked at on a case-by-case basis.

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

---

USGS:

From its inception over a century ago, USGS has made communication and dissemination of the results of its research an integral part of its mission. The USGS spends nearly $30 million per year on what can be called technology transfer in its broadest sense.

The fiscal year 1983 Congressional budget for the first time specifically allowed the USGS "to enter into collaborative projects and to accept contributions" from outside sources. This development has greatly increased USGS capability for cooperation with industry. The USGS and the minerals, fossil-fuel, and geothermal industries have had considerable information exchange for many years. Strict guidelines have been prepared on acceptance of contributions by the USGS and on cooperative research, the most important one being that results of projects must be open to the public. The USGS continues to encourage inquiries on cooperative research without actively soliciting joint projects. Owing to the sensitive nature of its mineral and energy properties, the oil and mineral industry is more sensitive than most to the public nature of joint cooperation. The NAS/NRC committee is addressing this problem to suggest future areas of cooperation between the USGS and industry. Examples include research on fossil-fuel and mineral-forming processes that should be of interest to many countries. A meeting to solicit industry's views is being considered.

BOM:

A long and varied association with industry has evolved at BOM. Currently, there are cooperative arrangements with industry for 144 specific activities

ranging in content from simple exchange, to technical information exchange, to joint planning, to research, to in-mine testing of proposed technology. In addition, cooperative arrangements with 12 industry associations are now in force. The BOM continues to encourage inquiries on cooperative research without actively soliciting joint projects.

The Committee on Mineral Technology Development Options of the NAS/NRC stated that the BOM should: (1) develop and implement cost sharing and cooperative efforts between government and industry and make them more effective; and (2) work closely with industrial research consortia developed by the various mineral industries. These recommendations are being implemented.

Recommendation 5-3: Simplification of Federal Procurement Procedures

---

BOM:

A concerted effort during the past few years has been made to reduce the number and dollar value of noncompetitive contract awards by BOM while still maintaining a strong working relationship with universities and colleges. Both recent legislation and policy directives have emphasized the need for competition. The result is that the normal procurement process has been lengthened, especially for R&D projects. Also, for most projects, universities must now compete against each other as well as against private organizations. Although P.L. 98-72 provides that "unique or innovative" unsolicited proposals need not be announced in the *Commerce Business Daily*, BOM has found that most of the unsolicited proposals received from educational institutions do not meet that exception to the extent that the offerer would be harmed by such an announcement. However, in order to reduce procurement leadtime and to avoid public announcement of proposed actions, BOM will use grants, rather than contracts, for deserving projects. This will also enable the BOM to meet its responsibility under the President's program to strengthen the capacity of historically Black colleges and universities to provide quality education.

BOM action to date has been minimal, since no simplification can be made until the General Services Adminstration (GSA) imposed procedures can be simplified. If anything, procedures have become more complicated with time.

DEPARTMENT OF TRANSPORTATION

MISSION

Recommendation 1-1: Mission Review

Department of Transportation (DOT) laboratories are primarily test and evaluation facilities with each laboratory's mission tailored to meet specific needs of an operating administration that deals with a single mode of transportation. The Transportation Systems Center (TSC), however, has as its mission the performance of study and analysis functions for the entire Department through annual program agreements (providing the funding to support the activities) with all of the major DOT organizations. Most of DOT's laboratories have recently been reevaluated and restructured, where necessary, to ensure consistency with evolving program goals. For example, as part of its evaluation of the Transportation Test Center (TTC), the Federal Railroad Administration (FRA) redefined the TTC mission to include broader transportation and other research and test issues, especially by non-government sponsors. At the same time, the "care, custody and control" of the entire laboratory facility was contracted to the private sector. Only safety-related railroad research continues to be sponsored by FRA at TTC.

On March 28, 1984, the Secretary appointed a Science and Technology Advisor for the Department. This action is in keeping with one of the recommendations of the President's Private Sector Survey on Cost Control which recommended that DOT should create, through the Office of the Secretary, an entity responsible for R&D policy and goal-setting, and monitoring. The newly appointed Science and Technology Advisor will be conducting a review to assure that recent evaluations/study recommendations are formalized and reflected in new laboratory mission statements and performance goals as part of a comprehensive assessment of departmental R&D programs. With respect to TTC, the FRA will continue periodic formal reviews with the private sector operator to assess the need for any required changes in the TTC mission.

It is anticipated that recommendations will be provided to the Secretary in the near future by the Science and Technology Advisor concerning departmental oversight of all DOT research and development activities. Depending on secretarial decision, an impact on all "mission" and "management" recommendations can be anticipated.

Recommendation 1-2: Size of Laboratory

The operating administrations of DOT have established systems through the budget process for the allocation of resources for all of their components, including the laboratories. Changes in the size of laboratory staff are dependent on assigned workload and overall personnel allocations. Requests for additional allocations are evaluated and if fully justified, temporary adjustments are made. Several laboratories are currently reviewing the size and composition of their staffs and taking actions to cut back

in certain areas and/or hire in others. For example, the Federal Aviation Administration's (FAA's) Technical Center has reduced functions not considered essential to the National Airspace System Plan and enhanced its role in the testing and evaluation of new computers and automated systems.

The Transportation Systems Center's staffing and skill mix are a function of its mission and workload because all funding is provided by various DOT organizations from their approved programs and in support of their specific needs. TSC is also subject to personnel ceiling limitations set by the Department, the Office of Management and Budget (OMB), and the Congressional budget process. There have been substantial reductions in force (approximately 20% of the work force) at TSC during the past 2 years, in response to Administration priorities, needed skill mix changes, and funding reductions.

A formal review of the first year of operation of TTC by the private sector indicated a misalignment of the labor skill mix based on the expected testing and revenues for the second year of operation. The private sector operator was free to implement the necessary adjustments based on anticipated mission requirements.

The Department will evaluate its use of established systems to control and monitor the size of the laboratories, increasing or reducing staff as appropriate, seeking all suitable opportunities for defederalization, and considering laboratory closing consistent with diminishing mission requirements.

FUNDING

Recommendation 3-1: Multiyear Funding

DOT receives no-year funding on an annual basis. Congress appropriates approximately 50% of the DOT pay raise requirements. The remaining pay raise cost is absorbed within DOT by reducing other object classification areas, such as overtime, travel, supplies, materials, and equipment.

Instability due to annual appropriation is not a problem. No recommendation is made for 2-year funding. DOT supports full pay raise supplemental.

No agency actions are required. OMB and Congress must approve pay raise supplemental.

Recommendation 3-2: Discretionary Funds

The DOT generally receives no discretionary funds. The concept is being reviewed along with other Grace Commission recommendations on R&D management.

The concept of discretionary funding is supported, but without establishing a specific percentage, since the mission and modus operandi of the laboratories vary with each Administration.

Each of various Grace Commission and Packard Report recommendations for DOT is currently under study. A decision as to the implementation of discretionary funding will be made in the context of these recommendations and in the context of other related management issues.

Plans are to resolve these issues in time for the next budget cycle.

Recommendation 3-3: Carry-over Funding

Appropriations for research and development are no-year funds. No change in funding is necessary to meet the recommendation. No action is required.

MANAGEMENT

Recommendation 4-1: Oversight Function

Several DOT laboratories have already established internal and/or external review committees. For example, TTC has set up several industry committees, including university advisory groups, to review proposed work and evaluate the quality of the reports, sponsor technical conferences, and support industry implementation of the results. In 1983, the Federal Highway Administration's (FHWA's) Fairbank Highway Research Center expanded arrangements for obtaining more extensive input from state highway agencies. Micromanagement does not appear to be a problem in DOT, and the committees have not been involved in this issue.

Recommendations will be presented to the Secretary in the near future for strengthening agency oversight of all DOT research and development activities. With respect to the laboratories, specific attention will be addressed toward assuring conformance with the thrust of this panel recommendation.

Recommendation 4-2: Greater Reliance on Peer Review

Basic research is not performed or funded at DOT laboratories.

Recommendation 4-3: Finite Term for Laboratory Director

DOT laboratory directors are held accountable, and their position descriptions and performance standards stress accountability and productivity. No finite term of appointment is formally addressed. The private sector operator of TTC has sole responsibility for the quality and productivity of the Center. Performance will be judged on the business he attracts from the private sector and on the ability to carry out specific research tests under the terms of task order contracts issued by FRA. Conditions for contract termination are specified in the 5-year facility contract which also has an option for 2 additional years.

DOT plans to continue the established system of performance evaluation to assure accountability, quality, and productivity. Implementation of this recommendation with respect to finite terms is currently being studied.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

The Department of Transportation, through its modal administrations, strives to keep the academic community involved in various transportation programs. The U.S. Coast Guard's R&D Center has had cooperative

efforts in the fire research area. The Coast Guard Academy facilities and faculty are shared with the academic community. The Federal Highway Administration has considerable involvement with existing programs of contract research by which states (with Federal aid) have close ties between state highway agencies and local universities. The Federal Aviation Administration, at its Civil Aeromedical Institute in Oklahoma City, allows regular use of its facilities for testing and evaluation of equipment and is encouraging further use of its facility by the university community and industry. The Research and Special Programs Administration, through its Transportation Systems Center in Cambridge, Massachusetts, has an excellent technical and contractual relationship with universities covering a variety of research subjects dealing with the entire transportation community. TSC has been the lead monitor for many DOT research contracts with such institutions as Worcester Polytechnical Institute, University of California at Berkeley, and the Massachusetts Institute of Technology.

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

---

Technology sharing is basic to the responsibilities of the Department. The Department of Transportation Act of 1966 specifically directs the Secretary to "promote and undertake development, collection, and dissemination of technological, statistical, economic and other information..." and to "...consult and cooperate with state and local governments." All elements of the DOT respond to this mandate and have set up a variety of mechanisms for the sharing of Federal technology, including: the dissemination of special "information packages" and newsletters, conducting technical conferences and planning meetings, the use of technical advisory and review committees, and the establishment of technology-transfer centers.

Each DOT operating administration typically has its own set of research programs and consultation mechanisms, often managed by an Associate Administrator for Research and Development or a similarly titled official. The various technology and knowledge sharing programs within DOT are structured to support the specific functions of each of the operating administrations. To assure support of broader departmental objectives, the Office of Intergovernmental Affairs' Technology Sharing Division in the Office of the Secretary of Transportation (OST) provides cross-program coordination. The focus of the OST work is on integrating the various operating administration efforts, providing needed policy support to them, and reaching constituent groups not contacted by the other elements.

The Department of Transportation manages nine laboratories engaged in R&D activities. The responsibility for technology transfer involving the laboratories rests within each of the operating DOT administrations. In support of the Stevenson-Wydler Act, the Office of Research and Technology Application (ORTA) contacts have been identified for each laboratory. Departmental oversight and coordination is provided by the Technology Sharing Program under the Assistant Secretary for Governmental Affairs

within the Office of the Secretary. Collaborative efforts between the laboratories and universities are encouraged.

Industry support of U.S. Coast Guard fire research is being carried on through equipment donations and services. The Federal Aviation Administration has many collaborative efforts in terms of equipment testing and direct funding support at both its Technical Center in Atlantic City, New Jersey, and Civil Aeromedical Institute in Oklahoma City, Oklahoma. The aviation industry regularly uses these facilities for test and evaluation of aircraft safety equipment as well as of communications, navigation, and other electronic devices. The Federal Highway Administration's Fairbank Laboratory in Langley, Virginia, has made it standard practice to establish cooperative agreements with industry and universities. The FHWA recently signed a contract with the American Iron and Steel Institute to conduct on a cost-sharing basis major experiments in its structures laboratory for the improvement of design concepts for steel bridges.

The Federal Railroad Administration's Transportation Test Center in Pueblo, Colorado, was turned over to the private sector in 1982 through a facilities contract for the "care, custody and control" of the test center. The R&D interactions of the TTC are facilitated through the use of industry oversight committees and consultants, as well as through the use of collaborative research programs. In these programs, both in-kind services and funding resources are obtained from industry. A "user fee" mechanism is applied to all non-Federal work done by the contractor in order to prevent unfair competitive practices in seeking outside work.

The Transportation Systems Center in Cambridge, Massachusetts, is a recognized leader in the study and analysis of transportation issues and problems. In the course of these studies, TSC creates, collects, and disseminates transportation-related data and information. TSC continually communicates the results of its activities, especially to colleges, universities, and the transportation community. This is accomplished through the Center's Office of University Research and Technology Sharing.

The DOT will continue to explore further cooperative arrangements with universities to utilize its laboratory facilities. The DOT will also explore new possibilities for cost-sharing research programs with private industry using its laboratory facilities.

Recommendation 5-3: Simplifying Federal Procurement Procedures

---

The DOT would welcome a simplified and liberalized mechanism for collaboration between R&D laboratories and universities or various industries to streamline cooperative R&D efforts. The strict provisions of the Federal Procurement Regulations (FPR), coupled with strictly structured funding procedures, inhibit this procedure.

At present, interactions between DOT laboratories and industry/universities are generally limited to specific contractual relationships presented in accordance with competitive FPR guidelines. Little opportunity exists for negotiated agreements, for joint R&D efforts partially funded by government and partially by industry, or for other innovative arrangements.

All service support contracts at the Transportation Test Center, formerly administered by the Federal Railroad Administration (FRA), are now executed solely through a private sector contractor. The contractor is not encumbered by Federal procurement procedures except where Federally funded research is concerned. The provision for obtaining the research needed by the FRA is incorporated into the basic facilities contract. This procedure greatly facilitates FRA contracting for research with the TTC operator, who represents the railroad industry.

ENVIRONMENTAL PROTECTION AGENCY

MISSION

Recommendation 1-1: Mission Review

The Environmental Protection Agency (EPA) places a high priority on maintaining current functional statements for its laboratories which clearly define their missions. From July 1981- July 1982, the Office of Research and Development conducted an in-depth study of the organization of EPA laboratories and decided that the current organizational structure was appropriate; however, EPA continues to incrementally review and revise the mission and organization of its laboratories to reflect changes in program priorities. In addition to continually reviewing and revising the mission of its laboratories, the EPA Office of Research and Development (ORD) plans to establish a Strategic Planning Staff whose function will be to study emerging environmental problems and determine: (1) whether research is warranted, (2) where research efforts should be focused, and (3) perhaps even how the research results would relate to current or proposed policy direction. The laboratories' missions will be redefined as necessary to accommodate the research efforts identified by the Strategic Planning Staff.

Recommendation 1-2: Size of Laboratory

EPA constantly reviews the size of its laboratories in relation to their missions. The Agency uses the flexibility available through the personnel system to relocate the work force as appropriate. Every attempt is made to vary the size of laboratories on the basis of long-term, major program shifts, rather than as a reaction to changes in one budget year. Experience has shown that there can be a resurgence in a program following a short-term reduction in resources. Because of the problems in staffing up or down, every effort is made to look at the long term. However, occasionally the budget process does produce major fluctuations in the resources available to support laboratories, and the size of the laboratory staff must be adjusted accordingly.

FUNDING

Recommendation 3-1: Multiyear Funding

EPA has never received a true multiyear appropriation. The Office of Research and Development currently receives two separate appropriations on an annual basis. One is for salaries and expenses (S&E), which is a 1-year appropriation and covers all the costs associated with conducting the in-house program. The second appropriation supports the extramural research and development program (R&D) and is a 2-year appropriation. However, this 2-year appropriation only contains sufficient funds to cover 1 year's expenses. A new 2-year appropriation is enacted each year. Pay raises must be covered by the S&E appropriation.

EPA wholeheartedly supports the recommendation that funding be authorized on a predictable basis. Resource instability and unpredictability are problems that have hampered EPA in its efforts to plan and implement a well-integrated research program. If fluctuations in the level of R&D resources could be eliminated, or at least substantially reduced, the R&D program would be greatly enhanced. However, requesting and receiving an R&D appropriation only every 2 years may not really help solve this problem. Stability over a longer period than 2 years is necessary, yet having the flexibility to ask for budget increases to support new program requirements is also desirable.

Funds also should be appropriated to cover pay raises. Agencies should not be required to fund pay raises from resources earmarked for other purposes.

Congress must approve these changes.

Recommendation 3-2: Discretionary Funds

The primary mission of EPA's laboratories is to support the Agency's regulatory program. Scarce resources leave very little flexibility to engage in research other than that required to support the Agency's client offices. EPA has an exploratory research program of $15 million to examine emerging environmental problems. These funds support research at colleges and universities in the form of grants and cooperative agreements. Also, 1% of the R&D appropriation is set aside to fund the Small Business Innovation Research Program. These programs provide a meaningful long-term research effort.

EPA generally supports the recommendation; however, support of the Agency's regulatory program must continue to be top priority.

The Agency should provide the laboratory directors greater flexibility in planning the projects to be conducted in their laboratories.

In fiscal year 1985 laboratory directors will have increased flexibility in conducting projects. Headquarters has reduced resource reporting requirements to allow laboratory directors greater discretion in managing the resources of their laboratories. To the extent that resources permit, in future years laboratory directors will be provided even greater discretion in planning and executing the research programs of their laboratories.

Recommendation 3-3: Carry-over Funding

EPA has a 2-year appropriation to support its extramural research and development program. To the extent that funds are available, the Comptroller allocates carry-over to Agency programs based on justifications of need and Agency priorities. Because of the time required to analyze needs and determine priorities, carry-over funds are frequently not made available to the laboratories for obligation until late in the fiscal year.

EPA supports this recommendation. Currently the Agency has the mechanism in place to enable the timely obligation and disbursement of carryover funds. However, because of the limitation of resources, the Agency must carefully consider competing priorities and allocate available carryover funds as required to best support the Agency's mission.

MANAGEMENT

Recommendation 4-1: Oversight Function

This recommendation is already being implemented at EPA. The Office of Research and Development reviews each research program at least once every 2 years and reviews proposed research on an as-needed basis. Review panels include research leaders from EPA and scientists from other government agencies, the academic community, and industry. This review process serves to evaluate how ongoing research is progressing and how proposed research is to be performed, that is, how scientifically sound the technical approach or experimental design is. This system assures that research funds are providing high-quality products reflecting good science and engineering; it also monitors performance and productivity. Although EPA has an ongoing external peer review process, the Agency has recently taken additional actions to make it even more effective. The peer review process has been decentralized to make it the responsibility of the laboratory director rather than a centralized management responsibility. Within the past 6 months, the Office of Research and Development has examined the delineation of the roles and responsibilities of Headquarters and laboratory management. Changes in management information requirements are being made to implement the appropriate division of responsibilities. These changes will further diminish the potential for micromanagement because the laboratory directors will be held responsible for accomplishments and outputs and overall utilization of their resources rather than being required to account for expenditures at the task or project level.

Recommendation 4-2: Greater Reliance on Peer Review

EPA sponsors research in the scientific and academic community primarily through two mechanisms which are both peer reviewed. One mechanism is the competitive grants program which was established in 1979 and is administered by the Office of Exploratory Research. Under this program, proposals are solicited each year and grants are awarded competitively based primarily on the recommendations of the scientific peer review panels. Another mechanism is for the individual laboratories to enter into cooperative agreements with the academic or scientific community. Prior to award, all proposals for cooperative agreements are peer reviewed by extramural reviewers who are experts in their field. The Office of Research and Development's policy is to broadly solicit applications and to award grants and cooperative agreements competitively,to the maximum extent practicable. All grants are awarded competitively, and any decision to award a cooperative agreement on a noncompetitive basis must be justified in a memorandum that is included in the project file.

Recommendation 4-3: Finite Term for Laboratory Director

EPA agrees that the laboratory directors must be held accountable for the activites in their laboratories. EPA laboratory directors are all members of the Senior Executive Service (SES) who have performance contracts that hold them completely accountable for the productivity of the laboratory. SES procedures allow a great deal of flexibility to reassign members as necessary and appropriate; however, this recommendation will be given further consideration.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

The 14 EPA/ORD laboratories are located on nine sites, all of which are within a short commuting distance of university campuses. Cooperative agreements with the institutions are in force.

The unique Clinical Studies Facility of the ORD/Office of Health Research is located adjacent to the University of North Carolina School of Medicine. The cooperative agreement stimulates collaborative programs and permits use of the facility by university staff.

Negotiations with the Coordinating Research Council of the Air Pollution Research Advisory Committee to utilize the ORD mobile source facilities at Research Triangle Park for a series of studies are currently in process.

An air pollution control research facility (Limestone Wet Scrubber) at Research Triangle Park has been utilized extensively by an industrial organization during the past several years.

The Unique Oil and Hazardous Material Spill Simulator Facility in Edison, New Jersey, has been made available to both university and industrial research teams.

The EPA Fluid Modeling Facility is made available to students at North Carolina State.

The University of Cincinnati operates ORD's Test and Evaluation Facility under contract. Additionally, graduate students from the University are provided the opportunity to conduct research at the facility.

In addition to ongoing activities aimed at encouraging university and industry access to Agency facilities, EPA recently implemented a new "Senior Visiting Scientists" program. This program is designed to bring some of the leading names in environmental science from universities and other institutions into EPA laboratories to conduct research. These scientists will help promote those areas of environmental science that are most significant to the Agency, and the program will help build closer working relationships between EPA laboratories and leading environmental scientists.

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

The automotive industry and EPA co-fund the Health Effects Institute to address studies pertaining to health effects presumed to be induced by automotive emissions.

The EPA Environmental Research Laboratory at Ada, Oklahoma, has been involved in collaborative studies with the American Petroleum Institute concerning land treatment of petroleum processing wastes.

Collaborative programs with industry in the development of pollution control systems (fabric filters, limestone injection technology, sequencing batch reactors, mobile treatment facilities, hazardous waste disposal technologies) have been a major component of the EPA research program.

Recommendation 5-3: Simplifying Federal Procurement Procedures

EPA is required to comply with the Federal Acquisition Regulation (FAR) and other government policies on procurement but, to the extent that there is any flexibility, the Agency is making every effort to simplify and streamline the procurement process. In 1982, EPA established a Procurement Review Task Force in response to Executive Order 12352 directing reforms in government procurement. The Task Force spent 10 months studying the problems surrounding the EPA procurement process, making recommendations for improvement, and effecting their implementation. Some of the results of that project are increased flexibility, elimination of redundancies and inconsistencies, reduced leadtimes, increased accountability, reduced paperwork, cost savings for the government and the private sector, and overall simplification of the procurement process within the Agency. The Office of Research and Development is in the process of revising Agency policy on management approval levels for procurement to provide the laboratory directors greater flexibility and authority than they currently have.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION

Recommendation 1-1: Mission Review

The National Aeronautics and Space Administration (NASA) annually prepares a long-range plan that defines and describes the objectives and programs for the agency and each of the centers (laboratories). In the past 3 years, increasing attention has been given to the contributions, roles, and well-being of the various elements of the NASA institution.

In 1981, a top-level review led to the consolidation of two smaller centers with two larger ones based on a determination of the best way to carry out related missions with available resources. The same year, three Associate Administrators, the principal program executives of NASA, were given responsibility for the institutional management of the centers. Included in their responsibilities is the advocacy and fostering of roles and missions for their centers.

The budget submission each year displays the missions and programs of the centers and provides the regular opportunity to review them. Major program initiatives, such as the Space Station, also require top management to look at the distribution of missions.

In 1983, NASA instituted a formal goals and objectives process. The agency goals and objectives were adopted with the participation and input of the center directors who were then instructed to formulate objectives supporting and elaborating on those of the agency. This year, NASA managers are reviewing the 1983 objectives for updating and modification. The underlying purpose of the process is to keep agency efforts focused on priority missions.

Recommendation 1-2: Size of Laboratory

NASA planning and budget processes include analysis of center manpower needs. There is an effort to avoid small fluctuations in response to normal program expansion or reduction so that a critical mass of relevant R&D competence can be maintained. This is often accomplished by adjusting the size of contractor support work forces.

However, the size of centers is responsive to major changes in program emphasis. NASA's overall civil service permanent complement has fallen from the Apollo program peak of over 35,000 in the late 1960s to under 22,000 today. Within that level, individual centers show marked differences based on major program changes. Marshall Space Flight Center, with a large launch vehicle and engine development mission, dropped from a high of over 7,000 to just below 3,500 now. Lewis Research Center dropped from 5,000 to 2,750 as some of its specialized programs declined in scope.

Reductions like these and the closing or consolidation of centers demonstrates conclusively that preservation of each laboratory has not been a mission.

FUNDING

Recommendation 3-1: Multiyear Funding

NASA has annual appropriations available for 2 years for its basic and applied research. The research program is a relatively small part of the agency's total program and is not specifically identified.

The basic and applied research activities are conducted in a manner that is synergistic with many of the developmental activities of the agency. To break out these research and development activities in a separate appropriation probably would subject them to more scrutiny in an environment not related to the overall mission of the agency and might result in more rather than less instability in the funding process. The 2-year availability of appropriated funds insulates against short-term instability, and continuing appropriations have not been a major problem to basic and applied research activities.

Recommendation 3-2: Discretionary Funds

Discretionary funding allocated to center directors constitutes approximately 4% of total in-house basic and applied research funds. The funding supports independent research, generally of a highly innovative nature, for which small expenditures are sufficient to establish whether there should be sustained effort or not. Accordingly, some activities "graduate" to regular R&D funding.

As recently as 1983, one center had discretionary research results cited for IR-100 Awards as "two of the 100 most significant new technical products of the year." The center directors make annual reports of discretionary fund activities to the Deputy Administrator, who subsequently relates funding levels to the performance of the centers. The reports are shared by all centers. The directors are authorized to fund both in-house and out-of-house work.

MANAGEMENT

Recommendation 4-1: Oversight Function

NASA has an Advisory Council and a network of advisory committees reporting to it. The members are eminent people outside NASA in aerospace industry, academia, and other areas in which they are in a position to give NASA advice. One of the concerns of the Advisory Council and its committees is the status of the center programs.

NASA will look to the Advisory Council for more activity in overviewing the continuing excellence of the centers. During the past year, the Space Systems and Technology Advisory Committee, headed by Robert L. Walquist of TRW, has been conducting a study of the "center of excellence" in roughly a dozen areas of technology at the research centers. They have

focused on the availability and quality of the center people, facilities, and programs in these specialized areas. The committee will report to the Advisory Council in the near future.

Recommendation 4-2: Greater Reliance on Peer Review

The NASA Advisory Council system, including its committees, provides an overall review of the agency's research and technology programs by outside authorities who are peers of NASA's researchers and research managers. Findings and recommendations are fed into the planning and budgeting processes. In addition, there is formal peer review of scientific activities.

INTERACTION WITH UNIVERSITIES, INDUSTRY, AND USERS OF RESEARCH RESULTS

Recommendation 5-1: Access to Federal Laboratories

Since its establishment in 1958, NASA has sought both advice and assistance from the university and industrial communities in determining and conducting research into problems of flight within and outside the Earth's atmosphere. This mutual effort to add to national strength has resulted in extensive and diversified relationships between university and industrial personnel and NASA research laboratories.

NASA has major interfaces with two closely related communities: aeronautics and space. In the area of aeronautics, universities and industry make extensive use of NASA ground-based facilities through a number of existing mechanisms. This program is working well and major changes are not planned. However, exploratory, four-way discussions are in progress among the following parties: (1) NASA aeronautics laboratories, (2) universities seeking to strengthen their graduate aeronautical engineering programs, (3) aircraft manufacturers interested in upgrading their engineering and design capabilities which will include not only traditional model test facilities, but also enable industry access to NASA's newly established supercomputer-based computational facilities, and (4) state government economic development agencies taking an interest in local aeronautics firms as part of their efforts to utilize science and technology for industrial development. These discussions are focusing on a model program that would combine graduate study with practical experience in both NASA field centers and industry design and production groups. If successful, such a program could be expanded to include other disciplines, industries, universities, and laboratories.

In the area of space, NASA facilities are physically located both in space and on the ground. The use of these facilities for *space technology* development has recently been addressed by a special study group, and the resulting actions are described under the NASA response to Packard Report Recommendation 5-2. The use of the NASA space facilities for *scientific research* is determined by open competition, and no changes in this area are appropriate or planned. However, the use of NASA ground facilities by the university and industrial scientific research communities

is an area that can be enhanced. It is planned that each NASA center will publish a document describing its applicable ground facilities in order to enhance their use by the total research and technology communities. The use of the facilities by such outside groups will be made a basis for the evaluation of the performance of each of the NASA laboratories.

NASA's university program is conceptual in nature and is a collection of diverse activities, which individually and collectively contribute to the agency's mission. The principal and most visible direct interaction between NASA and the university community is the support of university research and development projects. In fiscal year 1984, NASA funded approximately $230 million to educational institutions to conduct research in aeronautics and space science. Of this total, approximately 10% was used to update university instrumentation.

While sponsored research is the single largest activity fostering interaction and access to facilities and research programs, NASA is committed to discovering, developing, and facilitating new relationships with the academic community at all levels. To meet this objective, NASA has initiated a number of programs targeted at specific populations within the educational community. For clarification purposes, they are categorized as (1) university programs, (2) personnel programs, and (3) external education programs.

NASA sponsors a number of specific university programs that facilitate NASA/university interaction. Each year the agency provides opportunities for individuals to do post-doctoral research at NASA centers. This program is part of the National Research Council's Resident Associateship Program. In cooperation with the American Society of Engineering Education, NASA centers invite faculty members from across the nation to be guest investigators at NASA facilities during each summer. Beginning in 1980, the agency initiated a program to provide research opportunities for graduate students to conduct their thesis research at NASA facilities. Many additional programs, such as the Joint Institute for Advancement of Flight Sciences, Get Away Special, University Consortium, and Space Shuttle Student Involvement Project, aim to discover and develop talent and to increase involvement between NASA and the university community.

NASA continues to take advantage of the numerous personnel programs within the Federal government to foster interaction between students and faculty at all levels in the educational community and NASA laboratories. These programs, while affected by full-time equivalency limitations, still provide an excellent mode of fostering interaction. The cooperative education program continues to be a source of discovering new talent. NASA centers utilize co-op programs at the community college, baccalaureate, and post-baccalaureate levels in areas of secretarial science, engineering technology, engineering, and science disciplines. Additional programs, such as the Intergovernmental Personnel Act, Summer Employment Upward Bound, Presidential Management Intern, and the Pre-College Trainee programs, to name a few, all contribute toward multilevel interactions between NASA and the educational community.

Another important component in fostering relationships with the educa-

tional enterprise is the NASA External Educational Services Program. Targeted primarily at the primary and secondary education level, information on NASA's missions and results is provided to students and teachers in their academic setting to foster an interest in mathematics, science, and engineering. In addition, many NASA centers have developed teacher resource rooms that provide public-school teachers an inexpensive avenue to obtain films, video tapes, pictures, and information to supplement school curricula.

In addition to these activities, a joint NASA/National Academy of Sciences study group has been formed to recommend ways by which NASA-university relations can be enhanced. The report of this group is scheduled for the Fall of 1984. The recommendations will be evaluated and implemented if appropriate.

Recommendation 5-2: R&D Interaction Between Federal Laboratories and Industry

---

NASA has historically had close and extensive interactions between its laboratories and the aeronautics industry. This program is working well, and major changes are not planned. A special agency study, however, has recently been completed to determine how NASA can apply its experience in aeronautics to enhance R&D interactions with the aerospace industry. The study recommended 14 specific actions that, on April 3, 1984, were endorsed by the Administrator as agency policy. Particular attention will be given to establishing increased uses of NASA facilities in space, such as the Space Shuttle and the Space Station, by industry for technological development.

In addition, NASA is seeking new opportunities for cooperation with state government initiatives linking science and technology with industrial development. Several such opportunities for joint NASA-university-industry research and development programs, drawing partial support from state industrial-development sources, have been identified. "Centers of excellence" established at or in conjunction with universities under state auspices provide the focuses for most of these programs. The programs themselves would have the potential to facilitate intersectoral communication and technology transfer in aeronautics, space industrialization, and the non-aerospace use of NASA-developed technology.

The NASA Technology Utilization Program, an agency-wide effort involving and drawing on all of NASA's laboratories and R&D programs, continues to provide a variety of means for U.S. industry access to NASA technology. The program's management has, over its 20-year history, learned that it must rely on private sector industrial involvement to facilitate non-aerospace use of such technology. While much of this activity involves what might be called the "retailing" of specific items for individual products or processes, the program is now concentrating more heavily on "wholesaling," involving in some cases the transfer of generic capability, so that the acquiring industry can undertake a wide range of applications. The current directions and achievements of the NASA Technology Utilization Program are set forth in NASA's annual *Spinoff* publication.

Acronym Glossary

AD	Area Directors (USDA)
ANL	Argonne National Laboratory (DOE)
ARS	Agricultural Research Service
ASB	Army Science Board
BAO	Boulder Atmospheric Observatory (NOAA)
BNL	Brookhaven National Laboratory (DOE)
BOM	Bureau of Mines
CIMAS	Cooperative Institute for Marine and Atmospheric Studies (NOAA)
CIMMS	Cooperative Institute for Mesoscale Meteorological Services (NOAA)
CIRA	Cooperative Institute for Research in the Atmosphere (NOAA)
CIRES	Cooperative Institute for Research in Environmental Sciences (NOAA)
CODAR	Coastal Ocean Dynamics Applications Radar (NOAA)
DARCOM	Army Materiel Development and Readiness Command
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAES	Foundation for Advanced Education in the Sciences (NIH)
FAR	Federal Acquisition Regulation
FPL	Forest Products Laboratory
FPR	Federal Procurement Regulations
FRA	Federal Railroad Administration
FS	Forest Service
GMCC	Geophysical Monitoring for Climatic Change (NOAA)
GOCO	Government-Owned Contractor-Operated
GSA	General Services Administration
IPA	Intergovernmental Personnel Act
IR&D	Independent Research and Development Program (DOD)
IRI	Industrial Research Institute
JILA	Joint Institute for Laboratory Astrophysics (NBS)
JIMAR	Joint Institute for Marine and Atmospheric Research (NOAA)
JISAO	Joint Institute for Study of the Atmosphere and Ocean (NOAA)
LINAC	Linear Accelerator
LMC	Laboratory Management Council (DOE)
LMTF	Laboratory Management Task Force (DOD)
MFAC	Marine Fisheries Advisory Committee (NOAA)

NACOA	National Committee on Oceans and Atmosphere (NOAA)
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NCI	National Cancer Institute
NIH	National Institutes of Health
NMFS	National Marine Fisheries Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NPS	National Program Staff (USDA)
NRAC	Naval Research Advisory Committee
NRC	National Research Council (NAS)
NTP	National Toxicology Program (NIH)
NURP	NOAA Undersea Research Program
OMAR	Office for Medical Applications of Research (NIH)
OMB	Office of Management and Budget
ORD	Office of Research and Development (EPA)
ORNL	Oak Ridge National Laboratory (DOE)
ORTA	Office of Research and Technology Application (DOC,DOD,DOT)
OSD	Office of the Secretary of Defense
OST	Office of the Secretary of Transportation
OTTO	Ohio Technology Transfer Organization (NOAA)
PTI	Productivity, Technology, and Innovation (DOC)
RDT&E	Research, Development, Test, and Evaluation (DOD)
S&E	Salaries and Expenses (EPA)
SAB	Scientific Advisory Board (Air Force)
SES	Senior Executive Service
SPO	Strategic Planning Objectives (DOC)
SURP	Synchrotron Ultraviolet Radiation Facility (NBS)
TSC	Transportation Systems Center
TTC	Transportation Test Center
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

THE PROBLEM OF BIG PROBLEMS REVISITED*

Alvin M. Weinberg
Institute for Energy Analysis
Oak Ridge Associated Universities
Post Office Box 117
Oak Ridge, Tennessee 37830

Thirty years have passed since I first speculated on the future of the National Laboratories. To quote from my "Future Aims of Large-Scale Research":

> "Today's big scientific-technological problems cannot be expected to remain forever to challenge the institutions that were mobilized to cope with these problems...the (ultimate) viability of (these) institutions depends upon, and is limited by, existence of new problems of magnitude, scope and interest sufficient to challenge them adequately....(They) and their sponsoring agencies must inevitably be prepared to move into areas outside their original interests."[1]

Time has largely borne out these predictions, at least as far as the world's nuclear laboratories are concerned: most of the laboratories have taken on jobs unconnected with nuclear fission. In this essay I shall examine the history of this redeployment of the National Laboratories, particularly in the United States. Where has it been successful, where less successful? Do the areas the laboratories have moved into possess the social validity that merits support, and the scientific characteristics that match the capabilities of the laboratories? And can the laboratories continue to find new Big Problems to follow this generation's Big Problems--or will the laboratories lapse into a colorless survival, doing whatever a bureaucrat in Washington can pay for, irrespective of its significance in the resolution of serious social questions? My time horizon will be a long one, perhaps even a century, in keeping with the 100th anniversary of Daimler-Benz which we are celebrating.

The war-born Atomic Energy Laboratories represented the flowering of the era of Big Science. Though Ernest Lawrence's cyclotron laboratory at Berkeley, and perhaps the astronomical laboratories were harbingers of Big

*Contribution to the commemorative volume of Daimler-Benz, 1985.

57-279 O - 87 - 60

Science, the massive attack on nuclear energy by dedicated laboratories marked the full blooming of the style of Big Science. This style addressed big problems, used big equipment, and made big demands on the society that supported it.

The fate of the big applied nuclear laboratories might, in a curious way, be linked to the future of other institutions of Big Science--particularly the high energy physics laboratories. High energy physics, the Big Science aimed at elucidating the ultimate constitution of matter, had many of its roots in the quest for practical atomic energy. It was, after all, the Atomic Energy Commission that raised the money from Congress for, and then "owned," Brookhaven, the Fermi Laboratory, and the Stanford Linear Accelerator. Indeed, the Atomic Energy Act of 1954 gave cognizance to the AEC for high energy physics, largely because, at the time the act was framed, the connections between practical atomic energy and high energy research seemed to be closer than we would now judge it to be. No wonder that Professor John Wheeler, a distinguished theoretical physicist, quipped at a meeting of high energy physicists, "Nuclear fission is like sex. It is a subject not openly discussed in a gathering of high energy physicists. But each of us deep in his heart knows that were it not for fission, no less than sex, none of us would be here!" I suspect that this connection remains in the public's and politicians' minds, if not in the scientists'; the fate of nuclear energy and of the institutions directly concerned with its development to some extent may bear on the support and health of such fields as high energy physics.

Have the Nuclear Energy Laboratories Achieved Their Original Missions?

Most of the original nuclear energy laboratories have redeployed, at least in part, around problems unconnected with their original missions. Has this redeployment been premature? Have the laboratories achieved their original mission, which was the development of safe, practical, and economical nuclear energy? Of course, achievement of mission is only one reason for redeployment. If, as in Sweden, a political decision puts an end to nuclear power, then Studsvik has no choice but to disband or to engage in matters other than nuclear energy development. Moreover, much of the nuclear energy development has passed into the commercial sphere. Reactor manufacturers such

as KWU, General Electric, and Westinghouse possess powerful research establishments that are as capable in many ways as are the National Laboratories. Even if major development in nuclear energy remains to be done, are the National Laboratories the right places in which to conduct the development?

Before we can identify what still remains to be done in nuclear energy, we must examine nuclear energy's successes, its failures, its prospects. Since this is a topic that has been much discussed, I shall be brief, and shall focus on those aspects of the matter that are relevant to the question, "Have the National Laboratories finished their original job?"

Nuclear energy today is doing well in some countries, poorly in others. Though, by 1990, some 10 percent of the world's primary energy and 30 percent of its electricity will be generated in nuclear reactors, nuclear energy has, in most Western countries, become a source of political strife. No new reactor has been ordered in the United States since 1978. Sweden is scheduled to abandon nuclear energy by 2010, despite the generally superb operating record of its reactors, which now supply more than 40 percent of that country's electricity. By contrast, nuclear power is flourishing in France, in Japan, and in the Soviet Union. France and Japan, neither of which has indigenous fossil fuel, continue their massive deployment of nuclear reactors: France will have, by 1990, some 60 reactors which will produce 65 percent of that country's electricity; Japan, 35 reactors, accounting for 25 percent of its electricity. In between are countries like the Federal Republic of Germany, which now has 20 reactors producing some 24 percent of its electricity, but in which opposition to nuclear energy is serious and strident.

Where nuclear power has encountered the most difficulty, as in the United States, three interrelated factors are responsible. First, electricity demand has not expanded as fast as was expected in the early 1970s, and so several partly built reactors have been delayed or cancelled. Second, many nuclear reactors in the United States cost far too much; and, third, largely because of the accident at Three Mile Island, about half of the public doubts that nuclear energy is safe. The public's fears are translated into very burdensome regulation of nuclear power; and in the United States this, coupled with a fragmented utility industry and high interest rates, has led to outrageously

long construction schedules and some brutally expensive plants. In addition, the delay in sequestering high level wastes permanently has added to the public's dislike of nuclear energy.

All of this comes at the same time as environmental activism has become a powerful political force. Though one can make a strong case for nuclear power being one of the cleanest energy sources, environmental politicians choose not to accept this view: for them nuclear power is unacceptable largely because one cannot rule out, totally and absolutely, the possibility of a very large accident; and because high level wastes still are in temporary, not permanent, storage. Nuclear power, despite its many technical successes, remains an energy source under seige: in every Western country political forces are actively trying to stop it. In Denmark and Austria, they have succeeded; in the United States, the anti-nuclear forces have all but succeeded, though in this they have been helped by the extraordinary escalation in cost of nuclear power plants.

If one judges the success of the nuclear research establishment (and here I include the National Laboratories, private laboratories, universities) by the technical state of nuclear energy, one must conclude that the establishment has achieved a primary technical goal--competitive nuclear power. Most nuclear reactors operate reliably, and they produce electricity at competitive costs. That nuclear power is often too costly in the United States cannot be blamed on the technology, but rather on the ungainly, sometimes incompetent, handling by managers and regulators of what is a demanding and difficult technology. On the other hand if one judges the nuclear establishment by the degree of acceptance of the technology that it created, then one must conclude that it has failed: nuclear energy, which optimists like me had predicted would take over the world's energy system, has instead become a prime focus of political strife. Granted that the acceptability of nuclear power is largely a social, not a technological matter, its acceptance nevertheless is influenced by the technology. Can one therefore identify technological issues whose resolution would help restore the public's confidence in nuclear power, and which can and should continue to be pursued by the National Laboratories?

What Remains to be Done in Nuclear Energy Development

Three tasks for nuclear energy research still remain before one can claim that the first goal of nuclear energy--development of an acceptable energy source--has been achieved. First, and foremost, the existing fleet of reactors must operate reliably and uneventfully. Probably nothing is more important for the restoration of public confidence in nuclear power than 20 years of accident-free operation of the world's 400-odd reactors. Since these reactors are already built or well underway and are in the hands of utility companies, what the National Laboratories can do to help is limited. Yet these reactors in a way are still experimental devices--none of them has yet reached its design lifetime. By 2000, many of these reactors will be more than 30 years old. Can we identify what weaknesses will develop in these machines by that time, and devise remedies for these weaknesses? If radiation embrittlement of the pressure vessel is their Achilles heel, can one devise practical schemes for annealing the vessel and thus extending its life? Indeed, can one figure out ways of keeping the existing reactors operating long after their design life of 30 or 40 years? The economic benefit could be enormous. Since nuclear reactors cost relatively little to operate, they should produce very cheap electricity once they have been amortized--they are rather like dams in this respect. This realization is only now influencing reactor operators--Calder Hall, which has operated since 1956, has just had its license renewed. Will the Calder Hall reactors last as long as the Newcomen steam engine that finally shut down in 1918? And if electricity from reactors turns out to be cheap because reactors outlive their amortization time, would not the public accept nuclear because it is such a bargain? In brief, the reliable operation of the existing reactors and the extension of their life beyond their design life are central to the acceptance of nuclear energy: insofar as the National Laboratories can help in achieving these goals, they ought to be encouraged to work on their achievement.

A second avenue for continued investigation by the National Laboratories is, of course, waste disposal. I hardly need belabor this point, first because it is so obvious, and second, because the world's National Laboratories are busily engaged in solving the problem. And interesting and useful results are coming from these investigations: in France, over 500 million curies of radioactivity have been immobilized in borosilicate glass; in Australia,

SYNROC, an artificial leach-resistant rock for incorporating radioactivity, has been developed; at Oak Ridge, over a million curies have been permanently sequestered in grout sheets injected under high pressure into shale beds some 300 meters below the earth's surface. Although a tiny amount of radioactivity has leaked from the grout before it had set, I still regard this as a temporary set-back--the million-odd curies in the solidified grout is there forever.

As I look back on my own experience, I would regard our failure to sequester high-level radioactivity permanently in geological formations to be the greatest strategic blunder committed by the nuclear research establishment. We knew enough 20 years ago to immobilize high-level radioactivity in borosilicate glass, and to sequester it permanently in salt formations. Unfortunately, we could not imagine that our failure to actually demonstrate permanent disposal of radioactive wastes would torment the entire nuclear enterprise almost to death. To be sure, we could always argue that there was no technical reason to dispose of the wastes permanently: above-ground storage of spent fuel was adequately safe, and could be relied upon until we finally decided where to put the wastes. Moreover, above-ground storage was cheaper than was development of a geological disposal scheme--what we misjudged was the enormous public concern over our failure to demonstrate permanent disposal. And when, in 1970, we finally decided to sequester transuranic, and then high-level, wastes in a salt mine in Lyons, Kansas, only $25 million (in 1970 dollars) was allocated for the job--some 30 times less than a similar project would cost today! Here was surely a case of penny-wise and pound-foolish--and all of us who were involved must share the blame for allowing the waste disposal issue to become a primary social irritant, despite the availability of adequate technical methods for permanent geological waste disposal.

A third direction for nuclear energy research is the development of inherently safe reactors. Three Mile Island hangs over nuclear energy, an unwanted spectre that we cannot exorcise. To be sure, the probability of a large accident in an existing reactor is very small--of the order of 10^{-4} to 10^{-5} per reactor year, or even lower. But we cannot say that the probability is zero--and opponents of nuclear energy are quick to seize on this tiny possibility of a large accident to damn the entire technology.

Can reactors be designed to be inherently safe, rather than depending for their safety upon active intervention of mechanical and electronic devices, as

well as human operators? In recent years, several ideas for inherently safe reactors have been put forward, notably the Swedish PIUS reactor, and the German modular High Temperature Gas-Cooled Reactor. The possibility of an inherently safe reactor had not really occurred to the nuclear research establishment until very recently. I do not believe we have completed our job until one or even several inherently safe reactors are built: we can then judge whether or not such devices make economic sense. Indeed, I can hardly think of a task that would generate more enthusiasm within the nuclear research establishment than the development of an inherently safe reactor--an ultimate technological fix for the society's somewhat unreasoning, yet perhaps understandable, fear of a large reactor accident!

The three directions for research I have proposed--reliability/longevity, waste disposal, and inherent safety--are aimed at improving the social acceptability of the existing nuclear energy system. Eventually nuclear energy based on the existing light water converters will come to a halt because uranium is relatively rare--unless we can extract that element cheaply from the sea (which contains 4×10^9 tons of uranium), or unless we learn how to build safe and economical breeders. The incentive for such long-range goals must lie, ultimately, in our belief that the world will continue to demand more energy, and that the alternatives to burning uranium will always be inadequate to meet the demand.

The world's current primary energy demand of perhaps 10 terawatt years per year (i.e., 10 TW), hardly seems sufficient for a world 100 years from now. Though some energy revolutionaries claim to see a world of 2085 that uses but 10 TW, most of us would regard this as highly unlikely. China is industrializing, and so is India. Moreover, the world is electrifying: in 1950, 13 percent of the world's primary energy was converted into electricity, today it is 35 percent. If this trend continues (as analysts like C. Burwell predict), then we can look forward to a world in which 50 percent of its primary energy goes through electricity. Even if there is no expansion of total energy, this would mean 5 terawatts of primary energy converted into electricity. At an average load factor of 60 percent, this would require the equivalent of 2500 plants each with a capacity of 1 gigawatt of electricity. Were all of these power plants light water reactors, they would consume some 375,000 tons of uranium per year--an amount that would exhaust the estimated 20,000,000 tons of uranium at $150 per kg in less than 60 years.

then, in a completely orderly sequence of development, one would not build a second generation device until the first generation device has used up a reasonable part of its design life. Failure to observe this principle has been blamed by some for the technical unpleasantnesses encountered in the development of the light water reactors. For example, many steam generator failures probably could have been averted had all the lessons learned from early failures been incorporated in later reactors. Thus to have commercially viable breeders 50 years from now, the international community ought to build several first generation exemplars now; the experience we thereby gain will be invaluable for the next generation of breeders. Moreover, the United States ought to participate seriously in this enterprise.

Perhaps the most powerful reason for building breeders now, even though we do not need them, is to learn how long they will last. From the economic standpoint, the one advantage the breeder has over the light water reactor is its cheaper fuel cycle cost; moreover, this fuel cycle cost is essentially independent of the future cost of uranium. If a breeder outlives its amortization time, it becomes a source of extremely cheap energy--a gift, so to speak, which the generation that paid for the breeder bestows upon succeeding generations. The Experimental Breeder Reactor-II in Idaho has just observed its 20th anniversary, and it operates better today than it did the day it started to produce electricity. Thus the outlook for sodium-cooled breeders being more or less "immortal" is surprisingly good--but this must still be regarded as an attractive speculation that can be verified or refuted only with the passage of time and with the construction of several such reactors.

From this long-range point of view, the decision to cancel the Clinch River Breeder in the United States was unfortunate. Not once during the bitter debate that surrounded this decision was the CRBR's role in the study of the longevity of the breeder invoked as a justification for building it. In short, 50 years, a long time as human affairs goes, is hardly enough time to ensure the availability of an all-but-inexhaustible energy source based on uranium; we should be putting in place enough first generation breeders (such as CRBR) now so that the future can know, rather than guess, how long these devices will last.

How can one seriously claim that the National Laboratories have no primary mission in nuclear energy when the development of the breeder, together with its fuel cycle, still remains? Had I the power to allocate our

research resources, I would, within the field of energy research, place the breeder second only to those researches that might help ensure the success of the current era of nuclear energy--reliability/longevity; waste disposal; and inherent safety. Moreover, I would recommend that our approach to breeder development be broadened: the unilateral focus on the LMFBR to the exclusion of all competing breeders was largely a political, not a technical, decision. Perhaps out of the confusion that now surrounds the U.S. breeder program in the wake of the decision to cancel Clinch River might arise a new, broader approach to breeder development, an approach that would surely challenge the National Laboratories to their fullest.

Redeployments I: Project Sherwood

The first major redeployment of the National Laboratories was into controlled fusion--the so-called "Project Sherwood," to use the now discarded code name for this effort. Since the weapons laboratories, even at their inception, had worked on thermonuclear bombs, and had speculated on the possibility of controlled fusion, the establishment of Project Sherwood in 1952 hardly represented a total change in scientific direction.

Project Sherwood aims to create an inexhaustible energy source based on the thermonuclear burning of deuterium. Controlled fusion's ultimate social purpose is therefore the same as the breeder's: each is aimed at an inexhaustible large-scale energy source, the one based on burning the earth's residual uranium and thorium ("burning the rocks"), the other based on burning the deuterium in the oceans ("burning the seas"). Since the social purposes are identical, the two projects have always been in implicit competition, though both the Sherwood and the breeder community have always muted this competition lest it become an excuse for reducing support of both projects by enthusiastic budget cutters.

Were controlled fusion based on burning deuterium feasible and economical, I would agree that it is a better energy source than the breeder. Its raw material, deuterium, is probably easier to extract from the ocean than is uranium from low-grade ores, even though an isotope separation is needed. Though fusion is not without radioactivity, its wastes are much less radioactive than are those from fission. A fusion reactor produces no plutonium: insofar as one is concerned about the risk of weapons proliferation from

breeders, fusion reactors are less threatening. And even a partial meltdown in a fusion reactor had, at least until recently, been regarded as impossible.

These presumed advantages of fusion reactors may prove less decisive as engineers begin to design actual fusion reactors. Though scientific feasibility is yet to be demonstrated for any controlled fusion device, a reactor based on the tritium-deuterium (T-D) reaction requires less stringent conditions than a reactor based on D-D. The fuel for a T-D reactor is lithium, an element that, like uranium or thorium, must be extracted from the rocks, and which is nowhere near as abundant as deuterium. We now realize that fusion reactors will be radioactive, will require special handling, and will probably evoke objections from environmental activists. The induced radioactivity in a fusion reactor persists after the reactor has been shut down. G. Logan of the Lawrence Livermore Laboratory has pointed out that the resulting afterheat could in principle lead to a meltdown of some structure--that fusion reactors no less than fission reactors may not be unequivocally inherently safe.[3] He suggests, therefore, that designers of fusion reactors aim for inherent safety--which would require lower heat loadings, larger equipment, possibly higher capital cost. Others suggest the use of structural materials with little induced radioactivity as a more straightforward approach both to inherent safety and simpler waste disposal.[4]

Insofar as a fusion reactor that produces electricity reliably appears to be more difficult than one whose purpose is merely to manufacture fissile material from fertile material (the fusion breeder), some in the world's fusion community would shift the project's focus away from power production based on D-D or D-T to breeding fissile material. The energy system based on fusion breeders might consist of converter fission reactor "calves" fed by fusion breeder "cows" gathered in closely guarded centers. Most of the energy in such a system would come from the fission reactor calves; all the fissile material, and its reprocessing, would be confined to the few sites at which the fusion cows are located. One fusion breeder might provide enough fissile material to feed a dozen calves. This is in contrast to the fission breeder, in which one breeder could support only one ordinary converter.

The energy systems based on fusion-breeder and fission "calves," and the system based on fission breeder and fission calves are conceptually very similar. Thus in redefining this lesser goal for fusion, one can no longer claim

that the resulting energy system is less radioactive than is the system based on fission, since the fusion breeder itself as well as the light water reactor calves produce hardly less radioactivity than does the original fission system. And the fusion breeder handles large amounts of plutonium or uranium-233; to immunize such a system from the danger of proliferation would require careful control of the fuel cycle, just as in the pure fission system.

All that I have said about fusion so far assumes that controlled fusion, in some version, is scientifically feasible, and that it will prove to be both practical and economical. Though scientific feasibility is now often regarded as being on the verge of demonstration, I continue to be agnostic until the Lawson criterion has been exceeded in a fully realistic plasma; nevertheless, I am almost ready to believe that scientific break-even will be demonstrated in at least one of the new large tokamaks, and possibly in other configurations, within a decade. This would represent an extraordinary scientific triumph, one for which the world's National Laboratories would be justly proud. On the other hand, from scientific feasibility to economic practicality is still an enormous jump. Insofar as the focus might shift to the fusion breeder, rather than the power producer, the competition is uranium from sea water or from low grade ores at, say, $1,000 per kg; or the fission breeder. A gram of uranium-235 from $1,000 per kg natural uranium would cost about $200 per gram. Whether a gram of plutonium from a fusion breeder will meet this cost remains pretty much unknown; and whether the fusion breeder/light water reactor energy system is, all in all, better than the fission breeder/light water reactor system, we do not know.

In the past year the world has spent about $1 billion on the quest for controlled fusion; it has spent about twice as much on the fission breeder. Since the social purpose of these two projects is pretty much the same, one might argue that the amount spent on them should be comparable—<u>if they showed equal promise of achieving their goals</u>. Do fission breeders and fusion show equal promise of achieving their goals? This question has, as far as I know, never been asked seriously, at least not in a way that has affected any allocation of resources. At the risk of offending my many colleagues in the controlled fusion community, I would claim that fission breeders and fusion are in different universes as far as their promise is concerned: breeders have been built and they work; we still do not know whether fusion, even the fusion breeder, will work.

Project Sherwood has most of the characteristics that make it an ideal vehicle for redeployment of the National Laboratories. Its social purpose, inexhaustible energy, is impeccable. It requires large, expensive hardware, and so can be pursued effectively only in the style of Big Science. It remains an extraordinarily interesting and challenging scientific frontier. And because it is so far from commercialization, private support is largely out of the question: Sherwood will be supported by the public or not at all.

These four traits characterized nuclear fission in the earliest days when the National Laboratories were established. No wonder that controlled fusion has fitted so beautifully in the laboratories that developed fission--such as Oak Ridge and Los Alamos. Indeed, fusion is now the largest single project at the Oak Ridge National Laboratory. Moreover, as long as scientific feasibility has not been achieved, or, once it has been achieved, as long as economic practicality remains unproven, the fusion laboratories will not have worked themselves out of a job.

But, the longer it takes to achieve these goals, the more fragile will be the public's support of controlled fusion research. Thus the fusion laboratories face a dilemma: they will lose public support if success is too long in coming, and they will face heavy commercial competition if they achieve success.

Of the two, I suppose the loss of public support, rather than the possibility of commercial competition is by far the bigger problem. From this point of view, I would applaud the strategy advocated by some to focus on the fusion breeder, because the latter is easier to achieve than is the power producer. But in so doing, fusion comes into direct competition with the fission breeder. No longer can fusion claim superiority over fission because it is less radioactive, less prone to proliferation, less subject to accident. The fusion breeder is just that--a source of fissile material, albeit a more sophisticated source than is the fission breeder. And the energy system based on the fusion breeder is itself based primarily on fission.

The fusion community in the United States has not adopted the fusion breeder as its goal: this is still regarded as an incidental step to the achievement of the pure fusion power producer. Nevertheless, I would regard as fairly likely the eventual adoption of the lesser goal, the fusion breeder, simply because the public will tire of supporting the larger goal. Would the

public become weary of the quest even for the fusion breeder? I believe this will depend on the strength of our commitment to the inexhaustible energy system based on uranium and thorium--can this commitment be restored to the pre-eminent position in our social agenda that it enjoyed until the ascendency of the energy revolutionaries? In my earlier analysis, I concluded that breeders, whether fission or fusion, will not be needed until, say, 50 or more years. I argued for continued support of fission breeders because, as these technologies go, 50 years is not a long time. How much truer this is for fusion technology! Forty years have passed since Jim Tuck, Enrico Fermi, and Edward Teller at Los Alamos first raised the possibility of controlled fusion; we still have not exceeded the Lawson criterion in a practical plasma. Thus it seems to me that a rational resolution of the crisis of support that even the fusion breeder will face during the coming decade will require that a fission-based inexhaustible energy system be accepted as an important social goal--one that merits, say, the same kind of social commitment as does space exploration or even such expensive basic science as high energy physics.

Perhaps I am overly skeptical as to the strength of the commitment, at least in the United States, to the goal of inexhaustible energy based on uranium and thorium. But can one blame me for skepticism in the wake of the decision to cancel the Clinch River Breeder? Many of us saw this as a victory for those who find nuclear energy abhorrent: their target was not the Clinch Breeder, it was breeders in general, and therefore, ultimately, an energy system based on fission. The target of these opponents of fission surely encompasses the fusion breeder, no less than the fission breeder; that the fusion breeder has escaped their political attack I attribute to the rudimentary state of its technology. When, and if, fusion research reaches a point where a demonstration fusion breeder can be built, such a device will face the same sort of obstacles that finally killed Clinch River--unless the commitment to inexhaustible energy based upon fission is strong enough to withstand the political attacks from those who would find their personal fulfillment in the abolition of fission energy.

The other strategy, which I believe is more generally accepted by the fusion community, is to develop really clean fusion energy--based on pure fusion reactors that use radioactivity-free structural materials. Fusion power plants based on such materials would be immune from Dr. Logan's partial

melt-down; and they would simplify waste handling. Still, a 1000 MWe fusion reactor contains about 100 million curies of radioactive tritium; this cannot be avoided. Although this is far less than the 15 billion curies of radioactivity in the fission products of a 1000 MWe fission reactor, it is not negligible. I fear that, were the development of "clean" fusion power to succeed, opponents of nuclear power would still find reason to attack the development on the grounds that it is not clean enough.

Redeployment II: Solar Energy and Conservation

In 1973, as the first oil shock hit the world, Dixy Lee Ray, the chairman of the Atomic Energy Commission, was asked by President Nixon to prepare a plan for energy research and development aimed at achieving energy independence by 1980. The resulting document, The Nation's Energy Future,[5] set forth a wide-ranging menu of research on every energy source, and on conservation. The total budget for this expanded research program was 10 billions of 1973 dollars. Much of this was to be spent by the Atomic Energy Commission; in effect, a first step was thereby taken toward converting the Atomic Energy Commission into a Department of Energy with cognizance over all energy sources, not just nuclear energy.

In response to the initiative, the National Laboratories undertook research on solar energy, conservation, and energy storage. Many ingenious devices and insights have resulted: for example, the double focusing parabolic solar collectors, spun-off from high energy physics research at Argonne National Laboratory; the solar power tower designed and built by the Sandia Laboratory; ideas for more efficient and cheaper batteries; and, perhaps most significant, energy-economic modeling. The whole field of energy-economic modeling was in part born, and certainly was strongly nurtured, at the National Laboratories, equipped as they were with very large computers.

But the energy revolutionaries--those who argued that our energy problems could be resolved once and for all by conservation supplemented by solar energy--were not content with this redeployment. Even before their views acquired broad political acceptance in the Carter Administration, the political winds were blowing toward solar energy and conservation. I recall how, in 1974 when I was the director of the White House-based Office of Energy

Research and Development, we proposed the establishment of a separate Solar Energy Research Institute: a national laboratory devoted entirely to solar energy. Such an institute would be manned by people whose futures were tied to solar energy, and who would bring to the development of solar energy the enthusiasm and dedication that could hardly be expected of retreaded nuclear scientists at the existing national laboratories. The Solar Energy Research Institute was eventually established in Golden, Colorado. Though it enjoyed full support during the Carter Administration, it has been cut back by the Reagan Administration.

In Europe and in Japan, many of the original atomic energy laboratories have become, more or less, general energy laboratories, with major attention focused on solar energy in all of its manifestations--wind, photovoltaics, power towers, solar ponds, ocean thermal energy conversion, biomass--and, perhaps most important, conservation. And in several countries, the original atomic energy commissions have had their mandates broadened to cover all of energy.

How successful has this great redeployment been? By far the greatest success has been in conservation. The energy/GNP ratio in the United States fell by about 20 percent between 1950 and 1980. But it would be very difficult to attribute much, if any, of this improvement to any research or policy analysis that has come out of the national laboratories. During this period the price of energy has increased some 1.6-fold in constant dollars: what we see is largely a market response to increased price; it has little to do with research per se. Since the price of electricity has not risen nearly as fast as has the price of oil and gas, electricity has doubled its market share. This too may have contributed to the economy's higher energy efficiency since, as C. Burwell argues, electricity per se conserves primary energy, particularly in industrial processes.

As for solar energy, the results so far have been disappointing. To be sure, windmills have been built; wood is being burned; electricity has been generated in an experimental OTEC system and in a solar pond; a solar power tower operates near Albuquerque. But except where wood is cheap, the energy obtained from the sun is not cheap. The hundreds of windmills deployed in the Altamount Pass in California cannot be economically justified: they have been built largely as tax write-offs by wealthy speculators.

Though progress is being made in photovoltaic technology, a kilowatt hour from an unsubsidized photovoltaic installation in the United States costs more than 50¢. This is five or more times the price of electricity from new coal or nuclear plants. Thus photovoltaics have a very long way to go before one can count on them for a major part of our energy. Because electricity from them is intermittent, photovoltaics, along with many other solar energy sources, cannot provide reliable energy unless they are backed up--either by a grid energized by non-solar sources (or by many stochastic sources, such as widely dispersed windmills, some of which can always be counted upon); or by an affordable storage system. Indeed, the affordable storage system is both the Achilles heel and the Holy Grail of solar electricity: it is all but necessary, yet, so far all the proposed systems are too expensive.

I hope my generally negative assessment of solar energy is not discounted as sour grapes from an old nuclear enthusiast. Despite my impression that the redeployment into solar energy has not yielded very much, I remain convinced that a vigorous research effort, probably focused upon photovoltaics and upon storage systems, makes sense. In the broadest sense, I cannot argue as I have for a commitment to inexhaustible electricity based upon fission and fusion, without extending this commitment to solar electricity--which is also inexhaustible. Solar photovoltaics, after all, now produce electricity--which is more than can be said for fusion. That the electricity costs too much for general use is unfortunate--but certainly we ought not give up on reducing the cost. Moreover, the same arguments about longevity and cost that I invoked for the breeder system hold for solar voltaics: if photovoltaics last longer than their amortization time, electricity from them would eventually be all but costless! In short, the appropriate time scale for photovoltaics development is really much longer than has been generally recognized--and this, perhaps more than any other consideration, justifies their continued investigation in long-lived, governmental laboratories.

In a way, solar energy lends itself less naturally to investigation in large Big Science institutions than do either fission or fusion. Most of the solar devices are too small, and research on them is by and large small-scale, not large-scale. Perhaps, therefore, the main justification for conducting such research in governmental laboratories is its long range. Progress is likely to be very slow--too slow to merit much support from strictly

commercially-motivated entities. If solar energy is ultimately to become a truly large energy source, its development will require patience--more, I would judge, than can be afforded by market-driven industry. The redeployment into solar energy by the National Laboratories, and the establishment of the Solar Energy Research Institute, I regard as well justified.

Redeployment III: National Environmental Laboratories

Environmentalism as a major political force emerged in the United States in the early 1960s with Rachel Carson's Silent Spring. The National Environmental Protection Act was passed in 1969, and acts to protect the air and the water were passed soon afterward.

Even before all this legislative recognition of the environment, the National Laboratories had, since their inception, been obliged to study radioactivity in the environment. The Oak Ridge National Laboratory, for example, had one of the world's largest teams of ecologists, all engaged in studying the fate of radionuclides in the natural environment. All the laboratories were heavily engaged in the study of the effects of radiation on living things. Thus when environmentalism became a powerful political force, many of the national laboratories were well prepared to move into this area. Professor David Rose, while on leave at the Oak Ridge National Laboratory in 1971, went so far as to suggest the partial conversion of some of the laboratories into National Environmental Laboratories, which could examine both social and technical aspects of the environment. The idea was considered briefly by Senator Muskie, who had been responsible for U.S. environmental legislation: but the idea of converting the Atomic Energy Laboratories into Environmental Laboratories was too much for the Joint Committee on Atomic Energy to accept, and Professor Rose's original proposal was never adopted. Nevertheless, large laboratories devoted to certain aspects of environment now exist--the largest is the National Institute of Environmental Health Sciences, which is devoted to epidemiological and biological studies of the effects of the environment on health.

The National Nuclear Energy Laboratories, having primary responsibility for developing energy sources, can mount very broad approaches to the study of the environment: they can examine not only the environmental effects of

effluents from energy systems, but also, because they are intimately involved in the engineering of the devices whose effluents cause the problem, they can offer remedies for reducing the effluents. They are unique in this capacity to examine every aspect of the environmental problem.

One of the most important effluents is carbon dioxide; since 1975, the National Laboratories have been studying the CO_2 greenhouse effect. These studies range from estimates of the future atmospheric burden of carbon dioxide, to modeling of the effect of CO_2 on the global climate, to estimates of the effects of the resulting temperature rise on the environment. Of course, the laboratories' involvement with nuclear energy places them athwart a potent technical fix for carbon dioxide. I refer to a shift to nuclear power as a way of avoiding accumulation of CO_2. France, because of its massive commitment to nuclear energy, will throw less CO_2 into the atmosphere in 1990 than it did in 1980. If the ten countries that are now the world's largest users of energy could make the same shift to nuclear, the carbon dioxide problem would be pushed at least 50 more years forward. Insofar as the National Laboratories, by helping to solve the remaining problems of nuclear energy, can make this shift to nuclear energy more likely, they would be resolving the CO_2 environmental issue in an indirect, but powerful manner.

Altogether, I would judge the shift of the National Nuclear Laboratories into environmental studies to be among their most appropriate redeployments. The environment has no final resolution: there can hardly be a question of working oneself out of a job. No matter how clean the environment, one can always seek a cleaner environment. Nor is it likely that environmental research will be dominated by nongovernmental entities. To be sure, as governmental regulations become stricter, potential polluters will find it to their economic advantage to reduce their effluents; this has happened in the electric power industry, where the Electric Power Research Institute has launched a large research program on acid rain. But the environment is too public, and arouses too many political anxieties, for the government ever to shirk responsibility for the environment. In short, though David Rose's National Environmental Laboratories of 15 years ago were stillborn, they have been resurrected--not as full-blown, free-standing entities, but as important components of the original National Nuclear Energy Laboratories.

Redeployment IV: National Socio-Technological Institutes

Almost 20 years have passed since I suggested converting the National Laboratories into National Socio-Technological Institutes.[6] The argument for such a conversion was based on the observation that the society's concerns are never simply technological: there are always social components of any technical issue. Whether the concern is energy, or environment, or arms control, technology by itself is not enough. Insights and perspectives drawn from scholarly investigation in the social sciences ought to illuminate the issues. Thus originated the idea of National Socio-Technological Institutes: technologically oriented National Laboratories conjoined with think tanks. The think tanks would provide the social perspective; these social perspectives would help in the choice of new technological initiatives, and would help avoid the social dislocation that so often accompanies the introduction of new technologies.

The National Laboratories have, to a degree, become Socio-Technological Institutes, largely as a result of the energy shocks of 1973. The energy shock has brought economics to the National Laboratories: Oak Ridge, for example, now has some 20 economists. Once the ice was broken, other social scientists found congenial homes there. The environmental question has brought in geographers and ecologists. Political scientists, even anthropologists, can be found at Oak Ridge and at other National Laboratories, brought in because technology alone can hardly explain why people reject nuclear energy, or why they have elevated concern over low-level insults to the environment to such prominence.

Our whole Western society has become sensitive, perhaps overly sensitive, to the deleterious side effects of new technologies. This has led, in the United States, to the establishment of the Office of Technology Assessment, and, indeed to the Technology Assessment movement: a program aimed at identifying and forestalling unpleasant social consequences of the new technologies. The conversion of the National Laboratories into National Socio-Technological Institutes can be regarded as a manifestation of this movement.

Whether the social sciences per se are able to do what somewhat naive engineers and applied scientists expect of them--namely, to estimate the social impact of new technologies and to devise policies that might ameliorate

the growing tensions between technology and the public—this is very difficult to say. Technologists may be unaware that even within the social science community important figures such as Professor Lindblom have voiced doubts as to the proficiency of the social sciences in offering solutions for social problems.[7] Nevertheless, my experience with social scientists who are involved with technology assessment and risk analysis at the National Laboratories, convinces me that their perspectives and insights are useful, even though their prescriptions do not have the reliability of those of an expert in stress analysis, nor a theoretical sanction as solid as classical thermodynamics! But technologists ought not castigate social scientists: the problems they deal with are vastly more complicated than those dealt with in stress analysis or thermodynamics. Despite the limitations of the social sciences, one cannot doubt that their presence has given to the laboratories' technological ventures much more social sophistication and political sensitivity than was the case even a decade ago.

New Issues

I have identified four different problems around which the National Laboratories have remobilized: fusion, solar energy and conservation, the environment, and social implications of new technologies. I have also insisted that the original purposes of the National Laboratories—nuclear power that is fully acceptable in the short run and inexhaustible in the long run--have not yet been achieved. Until these goals have been achieved, the National Laboratories' original purpose remains valid. But reality is never so tidy: one does not suddenly reach an objective, and redeploy all at once--redeployment occurs over many years. The budget for fusion has grown to its present size over more than 30 years. We ought, therefore, to be thinking even now about new big problems that can occupy the National Laboratories when the vogue and support for the existing ones wanes. I shall suggest a few that seem important to me, though I make no claim that mine is an exhaustive list.

The growing role of Basic Research. When the National Laboratories were first formed during World War II, we drew no distinction between our applied research and basic research. Everything about the nuclear chain reaction was new: we would work on methods for solving Boltzmann's transport equation one

day, and then would apply our results the next day to the design of the Hanford plutonium-producting reactors. But as the science underlying the chain reaction was worked out, the basic science at the laboratories has diverged more and more from the applied work; and basic sciences grew relative to the latter as the applied work moved to the industrial laboratories.

This growing trend toward basic research at the National Laboratories was noted as long ago as 1965 by Dr. Arthur Vick, former Director of Harwell.[8] In a way it makes good sense, since basic research is open-ended and therefore fits well in a long-lived, government laboratory. On the other hand, the universities have traditionally been the home of basic research: as the National Laboratories have moved into basic research, they have run into competition with the universities--and this competition can never be entirely resolved.

One must distinguish between basic research that is part of Little Science--small groups of investigators working with small equipment; and basic research that is part of Big Science. On the whole, the competition I have mentioned is most severe where the National Laboratories conduct Little Science, which university researchers regard as their own province. Scientists at the National Laboratories generally are shielded from the peer review process that university scientists are subjected to, and this is regarded as being unfair by the universities. The National Laboratories, in justifying their conduct of Little Science outside the peer review system, argue that much of their basic research is relevant to the pursuit of underlying applied missions; that the individuals conducting basic research are available for help on applied jobs; and that, anyhow, the informal reviews of their basic research is at least as effective as is peer review in weeding out nonsense.

The role of the National Laboratories in Big Science is, of course, much less controversial. From their inception the laboratories afforded facilities that were unique--either because they were too expensive or too dangerous to be provided at the university. One need only mention the Zero Gradient Synchrotron (ZGS) at Argonne, the High Flux Isotope Reactor (HFIR) at Oak Ridge, or the Los Alamos Meson Production Facility (LAMPF) as examples. Here there is no question as to the appropriateness of such activities, nor is there any question as to their success. On the other hand, each of the laboratories faces a hard choice whenever a facility of this magnitude, which sometimes may dominate the entire laboratory, becomes obsolete. Or, when a new

instrument of Big Science is proposed, should it be built at an existing National Laboratory or at a new laboratory devoted specifically to this purpose? This issue arose at the time the Fermi Laboratory was built in Batavia, Illinois, just 50 kilometers from the Argonne Laboratory. The latter had already established itself as a successful high energy laboratory with its Zero Gradient Synchrotron; yet, the Atomic Energy Commission chose to create a new laboratory nearby. Judged by the success of the Fermi Laboratory, one cannot fault this decision, even though the Fermi Laboratory was more expensive than would have been an extension of Argonne to accommodate the huge new accelerator.

Altogether I would judge that the National Laboratories' role as facility centers wil continue to be a valid and appropriate role for them. LAMPF, HFIR, ZGS--all of these have been extremely successful; and as energies and intensities go up, one would expect that other such instruments will be built and used at the National Laboratories.

Applications of Nuclear Energy. Nuclear reactors produce electricity; yet electricity accounts for only 35 percent of the world's primary energy. Can nuclear energy be used for other purposes, in particular large-scale industrial processes and, even more important, automotive transport? Such a transition away from fossil fuel, if successful, might lead to a world no longer beset by a spectre of accumulating CO_2, or even acid rain. But the obstacles, of course, are enormous.

One of the first such ideas was R. P. Hammond's proposal in the 1960s for desalting the sea with heat from very large nuclear reactors. As we look at the economics today, the ideas seem naive--nuclear power is too expensive today to be used to desalt sea water. Suppose, however, the Bolsa Island project of 1968, instead of being cancelled, had been built. The project called for two 650 megawatt pressurized water reactors to provide electricity and 150 million gallons of water per day to the City of Los Angeles. Had the project gone ahead on its original schedule, it would have been completed before the cost of nuclear power had risen out of sight. Ten years later, the project would have looked very much better. And twenty years later--say, by 1995--Los Angeles would be grateful for the courage and foresight of the Metropolitan Water District for going ahead with the project.

Other schemes in this same genre are Professor Schulten's Adam and Eva[9]--a system that uses high temperature heat from nuclear reactors to convert methane and water into hydrogen and carbon monoxide which could then be shipped through pipes to process industries; or the many, so far unsuccessful, attempts to split water into hydrogen and oxygen with nuclear heat;[10] or even W. Haefele's scheme for devising an energy regime based on the conversion of fossil fuel to methanol,[11] and the all but complete sequestering or recycle of combustion products.

Whether bypassing of electricity is the key to wider use of nuclear power, or whether, as Burwell argues, the trend toward electrification we now are seeing will continue because traditional non-electric process industries are switching to electricity, remains to be seen. But generally, one must have sympathy for these attempts to visualize a more rational energy system, one that emits neither CO_2 nor acid rain, and that can be the basis for a long-term environmentally benign industrial society.

Technological Optimism and President Reagan's Dream

I realize that much of this must sound hopelessly, naively optimistic. But I would insist that the current technological pessimism that pervades our intellectual life is at least as overdrawn as was my technological optimism of 20 years ago. This atmosphere of technological pessimism could greatly complicate the future redeployment of the big laboratories. After all, the original mission of the institutions reflected an extraordinary leap of technological faith--that nuclear fission could be converted into something practically useful. Again, President Kennedy's commitment to put a man on the moon reflected a technological optimism of the highest order. The resulting big project matched admirably the character of the large space laboratories. And the largest redeployment of the nuclear fission laboratories, fusion, was based on an even greater technological optimism.

Have we lost this sense of technological optimism, have we given up our taste for large, non-market-motivated technological spectaculars? Are we so disenchanted with what some regard as the failure of fission as to prevent us from addressing new technological spectaculars because we cannot be sure that

they will succeed? Have we run out of ideas for major technological spectaculars that have enough plausibility to command the attention of large governmental laboratories and the support of the government agencies? Will the future of the laboratories lie in competent, indeed brilliant, picking away at small problems, no one of which matches in scale or even significance, such spectaculars as the breeder or fusion?

I do not know the answer to this. Yet, at the risk of antagonizing many of my European, as well as American, readers, I would call attention to a direction that certainly qualifies as a technological spectacular, that addresses the most important of all social issues, that demands unlimited technological optimism, and that may prove an ideal vehicle for redeployment of the weapons laboratories. I have thus far said very little about the nuclear weapons laboratories--Los Alamos, Sandia, Livermore--mainly because I am less familiar with them than I am with the nuclear energy laboratories. Nevertheless, I do not believe I compromise any national secrets by suggesting that further development of nuclear bombs can hardly lead to more than incremental gains. The laboratories, having sensed this, have redeployed into such things as fusion, solar energy, climatology, laser enrichment of isotopes, and monitoring of arms control agreements.

I would suggest that President Reagan's highly controversial Star Wars speech could serve to set the weapons laboratories along new technological paths that might have the most significant of all social purposes--conversion of the current posture of Mutually Assured Destruction to a posture of Mutually Assured Survival. President Reagan, in his March 23, 1983 speech, displayed an extraordinary, some would say foolhardy, technological optimism. He called for the technical community to come up with a leakproof shield against ballistic missiles--a shield so perfect that, as he put it, peace would no longer depend on each side holding hostage 100 million of its opponents' citizens. Technology was being called upon by the President to rescue humankind from the extraordinary predicament into which technology had placed it.

This degree of technological optimism from a president of the United States exceeded by far President Kennedy's call for the moonshot: it exceeded, even, President Roosevelt's call for an atomic bomb. As visualized by the President--an all-but-perfect area defense against ballistic missiles, so

efficient that citizens need no longer fear the spectre of nuclear war--this goal is unattainable. Many, if not most, of the scientists who had been involved in arms research were quick to denounce the President's call as being impossible. More than that, many in the arms control community argued that an area defense, even if it could be achieved, was destabilizing. If the United States deployed such a defense, it need no longer worry about a retaliatory strike from the Soviet Union. Such deployment would, therefore, be viewed by the Soviet Union as prima facie evidence that the U.S. was planning a first "counterforce" strike against Soviet retaliatory weapons; the U.S. defensive system would be adequate to take care of the Soviet's ragged retaliation.

Not all scientists regarded President Reagan's proposal in this light. Perhaps most prominent was Professor Freeman Dyson of the Institute for Advanced Study: in his Weapons and Hope, he called for a transition to a defense-oriented instead of an offense-oriented world.[12] Dyson came to his somewhat unorthodox views as a result of his experience as an operations analyst in the Royal Air Force in World War II. He concluded that defense is morally superior to offense; and though he fought for the British, his sympathies were with the German fighter pilots who tried to thwart the British-American bombing raids on Berlin and Dresden.

Two years after Reagan's call for defense, I believe one is seeing a gradual shift in attitude toward Star Wars. No one seriously believes a defense that can fully neutralize nuclear bombs delivered by cruise or ballistic missiles is possible. Yet many analysts concede that even an imperfect defense could be useful, and that a partial defense of missile silos is feasible. Such a defense would extract a "price" of, say, eight re-entry vehicles for every silo destroyed. Such an imperfect defense in effect diminishes the effectiveness of the opponents' first strike weapons; one therefore need not maintain as many of one's own weapons to maintain de facto parity. In short, deployment of an imperfect defensive system around one's own silos reduces their vulnerability and thus adds to stability.(This was exactly the argument offered for the "race track" basing mode of the MX--to reduce vulnerability.) Moreover, one needs fewer weapons to maintain a balance if the weapons are afforded a degree of protection against incoming ballistic missiles: the defense system can in principle serve as a shield behind which one can dismantle some offensive weapons--that is, exchange one

kind of parity, a mixture of some defensive and some offensive weapons--for a more threatening parity that involves larger deployment of offense alone. Mutually assured destruction still operates, but at a lower force level. Dr. Jack Barkenbus and I have called this strategy "Defense-Protected Build-Down"[13]--i.e., a build-down, negotiated or even unilateral, made politically feasible by the erection of a defensive shield, even an imperfect shield.

Two other points have emerged that blunt some of the opposition to Star Wars. First, and perhaps most important, all war, and particularly nuclear war, is uncertain. Had Admiral Tojo foreseen the ultimate outcome of the attack on Pearl Harbor, or Adolf Hitler the outcome of Barbarossa, would these operations have been launched? Defensive systems add to the uncertainties facing a would-be attacker. As Donald Snow says in his The Nuclear Future,[14] anything that increases the uncertainty of the outcome of a nuclear war will reduce the likelihood of a nuclear war.

The second point is one that has always troubled defense analysts, but has never been resolved. If two parties engage in an offensive confrontation, they achieve parity when both sides have the same number of first strike weapons. If three parties engage in such confrontation, parity is impossible to achieve (unless no party has any weapons) because each party would require as many weapons as the other two combined. This troublesome point was generally regarded as too theoretical to be of much interest. Yet the Intermediate Nuclear Force negotiations foundered on exactly this point, with the Soviet Union asking for as many warheads as the United States, England, and France combined, the United States demanding parity with the Soviet Union alone. This n-party offensive instability disappears if all sides deploy only defensive weapons; and this stability persists in a mixed offensive/defensive posture as long as each party's defense is strong enough to destroy all offensive weapons that might face him.

I apologize for this digression into the Talmudic niceties of arms control theories. Yet, I believe some such arguments are necessary to justify what is perhaps the major redeployment that is now going on in the U.S. laboratories--the development of non-nuclear defenses against ballistic missiles. President Reagan has proposed spending $26 billion on his Strategic Defense Initiative; though this leap of technological faith is regarded by many as wrong-headed, both technically and politically, I cannot agree for the reasons

I have touched upon. I believe Freeman Dyson is fundamentally more correct than are his detractors: we are more likely to rid the world of the curse of nuclear weapons from a position of defense than from a position of offense. The laboratories will be fulfilling a noble, not an ignoble, social purpose if they can devise the technologies that can allow the world to make this transition from offense to defense. Moreover, European and Israeli laboratories may be drawn into this quest: the United States has invited laboratories in these countries to participate in the Strategic Defense Initiative. Perhaps this is a first step in internationalizing ballistic missile system defense, a possibility held out by President Reagan.

Thus far I have spoken only of defense against strategic weapons; what about defense against tactical weapons, or even against conventional armor carrying conventional armaments? This, after all, is the problem faced by Europe: can NATO safely adopt a no-first-use nuclear policy; and can it match the Warsaw Pact's armor by means of clever defensive weapons? I am much influenced in these matters by the views of the former Assistant Secretary of Defense for Research and Development, Dr. William Perry. Speaking at Los Alamos in 1982, Dr. Perry insisted that defensive weaponry had become so effective that it was no longer necessary for the West to match the East tank-for-tank.[15] If this was the situation in 1982, can we not look forward to a future 10, 20, 30 years from now when defensive systems become so overwhelming that neither non-nuclear nor nuclear aggression makes sense? And would not the research institutions responsible for providing the technologies that make this great transition possible be fulfilling the greatest social purpose of all--the elimination of organized armed conflict as a means of resolving political disputes? I realize that all this must sound impossibly idealistic, perhaps having little to do with the real world. But President Reagan's March 23, 1983 speech was part of the real world, however much it annoyed arms control intellectuals. The President displayed a technological optimism whose absence I have repeatedly decried. This optimism, though overblown, I found refreshing; and, as the years go by, we will learn whether the optimism is misplaced or will lead to the safer world all of us, especially President Reagan, seek.

Technological Pessimism and Basic Science

I have spoken almost entirely of the challenges that face the Nuclear Energy Laboratories as their original mission disappears, and they scramble for survival in the face of a widespread technological pessimism. But, as I said earlier when I quoted John Wheeler, the connection between fission and the most arcane parts of Big Science--High Energy Physics or even Heavy Ion Nuclear Physics--though conceptually weak, remains strong in the common organizational sources of support for both nuclear energy research and high energy physics, and possibly in the public's perception of a linkage. Is it possible that continued disenchantment with nuclear power, coupled with the growth of the Green anti-technological movement, whose primary target is our modern technological society--that this technological pessimism wil spill over to a disenchantment, and therefore loss of support, for basic big sciences that are, rightly or wrongly, regarded as having nuclear connections?

So far these sciences seem to have escaped unscathed, at least in the United States. And, I suppose the possible military application of ion beams could serve as a basis for support of accelerator development, even of accelerators having little to do directly with military hardware. Moreover, in the United States, basic sciences generally and High Energy Physics particularly, have fared well under the Reagan Administration. But the costs of these sciences continues to rise. The Super-Conducting Super-Collider is estimated to cost several billions of dollars; can an expenditure of this magnitude survive future political buffeting without a clear and continuing popular mandate for such inquiry?

One certainly cannot say. I should think, however, that a political climate supportive of such arcane, yet extremely expensive, investigation is more likely to flourish where science per se is seen as man's servant, not as man's master; where technology is perceived as being good, not bad; where technological optimism, not technological pessimism, holds sway. In short, the success of the great technological adventures of this century--most notably nuclear power--is not unrelated to the future success of Big Science itself, even those parts of Big Science that have traveled far from their roots in fission. One hopes that the current fashion of technological

rejection will prove to be a passing phase, to be replaced by a renewed faith in our big technologies, which are based on continuing achievements of the establishments of Big Science.

AMW:bc
4-16-85

References

1. A.M. Weinberg, "Future Aims of Large Scale Research," Chemical and Engineering News 47, p. 2188, May 23, 1955. See also Reflections on Big Science, MIT Press, Cambridge, Massachusetts, 1967.

2. W.B. Lewis, "Breeders Are Not Necessary--A Competing Other Way for Nuclear Power," Report DM-69, Atomic Energy of Canada Limited, p. 1686, January 15, 1963.

3. B. Grant Logan, A Rationale for Fusion Economics Based on Inherent Safety, UCRL-91761, Lawrence Livermore Laboratory, Livermore, California, 1984.

4. Report of the DOE Panel on Low Activation Materials for Fusion Applications, Center for Plasma Physics and Fusion Engineering, University of California at Los Angeles, June 1983.

5. Dixy Lee Ray, The Nation's Energy Future: A Report to the President, U.S. Government Printing Office, Washington, D.C., 1973.

6. A.M. Weinberg, "Social Problems and National Socio-Technical Institutes," in Applied Science and Technological Progress, pp. 415-434, U.S. Government Printing Office, Washington, D.C., June 1967.

7. Charles E. Lindblom and Davis K. Cohen, Usable Knowledge, Yale University Press, New Haven, Connecticut, 1979.

8. F.A. Vick, in The Organization of Research Establishments, Sir John Cockcroft, (ed.), p. 62., Cambridge University Press, London, 1965.

9. See, for example, K. Kugeler, M. Kugeler, H.F. Niessen, and R. Harth, "Development of Helium-Heated Steam Reformers," in Gas-Cooled Reactors with Emphasis on Advanced Systems, Proceedings of a Symposium, October 13-17, 1975, Volume 2, pp. 3-20, International Atomic Energy Agency, Vienna, Austria, 1976.

10. See, for example, W. Haefele, Energy in a Finite World, pp. 730-734, Ballinger Publishing Company, Cambridge, Massachusetts, 1981.

11. W. Haefele, "The Concept of Novel Horizontally Integrated Energy Systems in the Case of Zero Emissions," International Institute for Applied Systems Analysis, Laxenburg, Austria, 1984.

12. F. Dyson, Weapons and Hope, Harper and Row, New York, 1984.

13. J. Barkenbus and A.M. Weinberg, "Defense-Protected Build-Down," Bulletin of the Atomic Scientists, 40 (8), pp. 18-23, October 1984.

14. Donald Snow, The Nuclear Future: Toward a Strategy of Uncertainty, University of Alabama Press, University, Alabama, 1983.

15. W. Perry, "Technological Innovation: The National Security," in Science, Computers and the Information Onslaught, Academic Press, New York, 1984.

○